JOURNAL OF

# METALS

DECEMBER 1960

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JOURNAL OF

# METALS

Vol. 12, No. 12
December, 1960

**COVER:** "And on to the 18th Annual Electric Furnace Conference"—David Coin's cover depicts air induction melting and this issue gives emphasis to the entire area of electric furnace metallurgy.

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# personnel

• These items are listings of the Engineering Societies Personnel Service, Inc. This Service, which cooperates with the societies of Civil, Electrical, Chemical Mechanical, Mining, Metallurgical, and Petroleum Engineers, is available to all engineers, members and non-members, and is operated on a nonprofit basis. If you are interested in any of these listings, and are not registered, you may apply by letter or resume and mail to the office nearest your place of residence, with the understanding that should you secure a position as a result of these listings you will pay the regular employment fee of 60% of the first month's salary if a non-member, 50% if a member. Also, that you will agree to sign our placement fee arrangement which will be mailed to you immediately after receiving your application. In sending applications be sure to list the key and job number.

• When making application for a position, include eight cents in stamps for forwarding application to the employer and for returning, when possible.

## —MEN AVAILABLE—

*All those listed under "Men Available" have membership in the AIME.*

**Senior Metallurgical and Material Engineer,** ChE, MS Met. Eight years recent direction and supervision of defense, including Washington; broad, forefront materials R&D. Recognized as one of Ti industry founders; R&D, management, chief metallurgist; consultant including end-item fabric. Permanent location open or consult from Connecticut. M-246.

**Sales-Engineer,** MinE, 41. Eight years experience with one of the major steel producers in the West as sales engineer. Sales and service of steel products to mining and manufacturing industries of Arizona. $10,800. Prefer west. Home: Arizona. Se-113.

**Metallurgical or Chemical Engineer,** MinE, plus training in chemical. Three years chemical analytical. Eighteen months chemical engineer in charge of waste control and stream pollution. Eighteen months metallurgical engineer in charge of heat treating atmosphere and physical control program. Supervisor of diversified metal production line. $7200. Any U.S. location. Home: West Virginia. Se-1367.

**Mine, Mill Superintendent,** Mining plus management, 44. Twenty years experience staff, manager, assistant chief engineer, engineer—large phosphate, sulfur, acid, fertilizer operation. Responsible for property, transport, warehouse, purchase, accounting; for production, shipping service. For beneficiation, production, equipage, labor, for surface and underground, planning and operation. $12,000 up. Any location. Home: Southeast U.S. Se-1872.

**Mine or Mill Superintendent,** MinE, 46. Over twenty years experience, sinter, gravity, flotation of manganese, iron, copper, tungsten plus metallurgical design, chemical process for operation, engineers, producers. $9600 up. Any location. Home: California. Se-1857.

**Mine, Mill Superintendent,** MinE, 31. Six years experience, 1 year engineering for metals, mine and mill; one year gypsum layout and survey; one year open pit iron stripping, track and road layout, reserves; two years military building, survey and supervision, and design steel. $9100. Prefer northwest or western U.S. Home: Canada. Se-1846.

**Mine, Mill Manager,** Age 53. Twenty-five years experience including complete charge of lode gold operation, power plants, shops, camps, mines and mills; underground design, construction and operation of mines and mills, railway system (gold, lead, zinc, copper). $12,000. Prefer: Latin America, U.S., Orient. Home: California. Se-1790.

**Process Metallurgist,** Age 38, I. E. Five years experience in basic oxygen furnace design, metallurgy, and L-D process data studies with West Coast engineering company. Desire position with responsibility and opportunity with progressive steel company or foundry in research, development, operations, or sales. $10,000. Prefer west. Home: California. Se-1585.

**Mill Superintendent,** Age 46. Twenty-one years experience in charge of plant operations, director of research, organizing test procedures, supervising mill sampling and personnel. $9000. Prefer, western U.S. Home: Arizona. Se-565.

## ——POSITIONS OPEN——

**Research Assistant,** prefer BS in physical metallurgy, physical chemistry or physics. Opportunity for graduate study and fundamental research at major eastern university leading to MS or PhD in materials science. Full time research during summers. W9791.

**Pickling Line Supervisor** with chemical or metallurgical engineering training and at least 5 years steel processing experience including coil pickling. Spanish desirable. $12,000-$13,-800 year. South America. F9725.

**Sr. Marketing Executive,** Inorganic and metallurgical products, with record of successful marketing and sales management experience preferably in the chemical or metallurgical field, to plan and manage all aspects of marketing program; maintain, equip, and personally support in the field a small, well trained organization to carry out program; to direct all marketing operations. About $20,000 year base salary plus incentive earnings opportunities; usual fringe benefits. New York City. W9708.

**Sales Manager,** electronics, metallurgical or chemical engineering graduate, experienced in application of molybdenum and tungsten to electronics, welding and metal spraying industries, to control national marketing and sales functions. Salary to $15,000 year. Maine. W9704.

**Director of Product Development,** engineering graduate, with at least 10 years managerial and administrative experience in design and application of non-ferrous metal products. $20,000-$24,000 year. South. W9697.

**Metallurgist** with thorough knowledge of metallurgy and related chemistry, to assist in the establishment and organization of a laboratory for the production, control and testing of tools and dies for a factory which produces steam boilers. Duration, 8 months with possibility of extension. Salary good. Europe. F9692.

**Metallurgist,** Materials Engineer, graduate, with about 5 years experience for advanced materials development for electronic and electrical devices. Magnetic materials, contact materials, conductor materials; process and properties studies. $10,000 year. Upstate New York. W9681.

**Metallurgists,** experienced in vacuum metallurgy, powder petrology, metallurgy of non-ferrous and non-refractory metals and semi-conductors. Salary open. Canada. Sj-5631 (a).

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Address replies for positions to the nearest local office of the Engineering Societies Personnel Service, Inc., *not* to the JOURNAL OF METALS. Offices are located at 29 E. Madison St., Chicago 1, Ill. . . . 57 Post St., San Francisco, Calif. . . . and 8 W. 40th St., New York 18, N. Y.

**Foundry Technologist** to conduct development research through operation of small foundry. Principal activities directed toward development of green sand molding compositions. Experience in basic foundry practice desired with degree in chemistry, chemical engineering or metallurgy. Salary commensurate with experience and degree. Southwest. W9665.

**Welding Engineer,** experienced in welding all types of work on heavy and exotic metals. Advise, consult on welding operations, both in marine, fabrication, erection, and shop. Train personnel, order equipment and materials, set up procedures. $7200 up, depending on qualifications. San Francisco East Bay. Sj-5646.

a) **Metallurgist,** Met, under 40, experienced testing and operating for copper concentrator (open pit). Salary open. b) **Assayer,** to assist chief chemist running routine copper assays. Salary open. No age limit. Arizona. Sj-5642.

**Mine Manager,** MinE or Met, over 30, at least five years experience with mine operation and management, non-metallics. Must speak fluent Spanish. Prefer Mexican citizen, will consider U.S. citizen, who has worked in Mexico. Salary open. Mexico. Sj-5622.

**Mine, Mill Superintendent,** thoroughly capable man with recent experience operating mine and mill. Able to carry 100-man operation with two American assistants from development state through full operational stage. Must be able to speak Spanish. Family quarters approximately one hour from property. For operating company. $12,000. Mexico. Sj-5616.

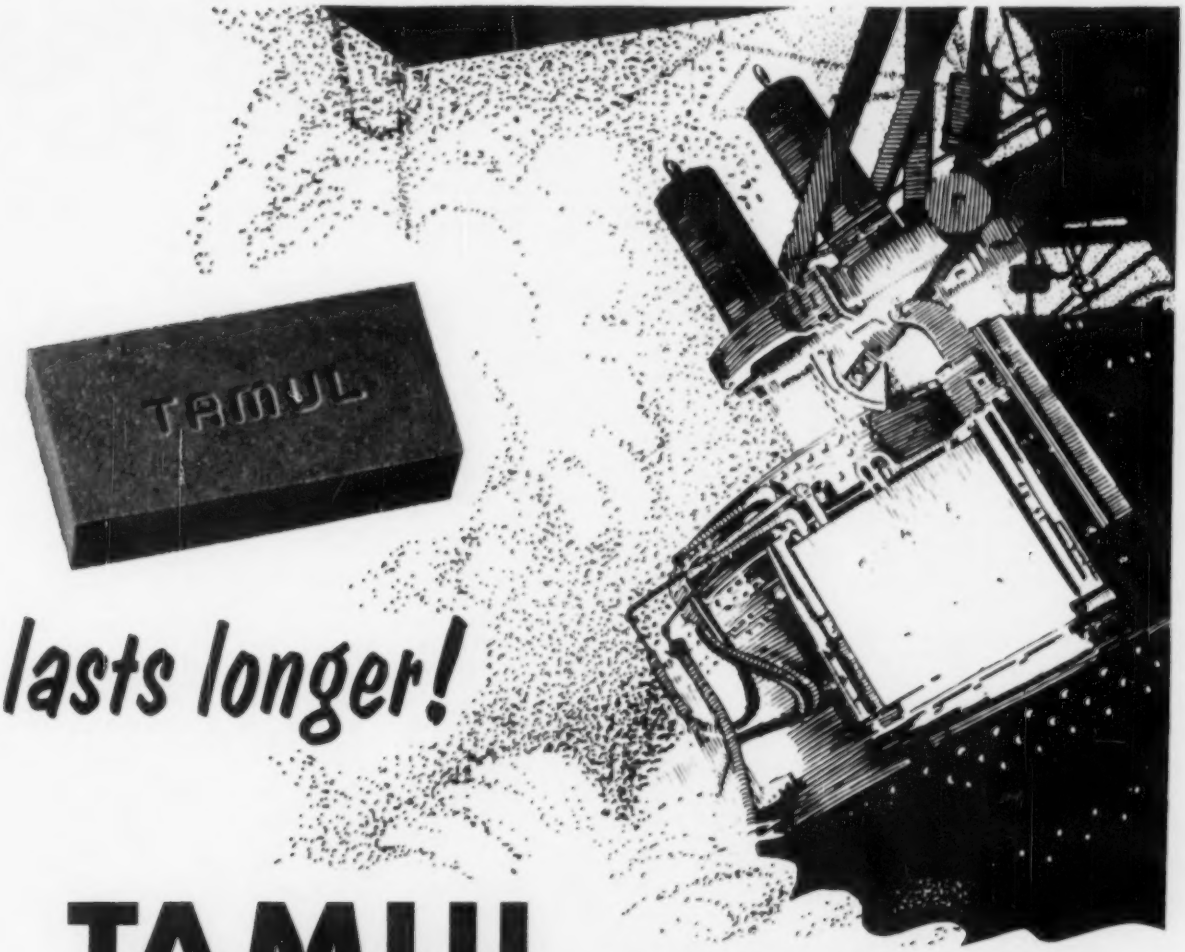
## NEW BULLETIN

A new bi-weekly bulletin of "Engineers Available" is now being published by the Engineering Societies Personnel Service, Inc. Distributed free of charge, the bulletin contains synopses of the experience of engineers who have registered with the Service and are seeking a new position.

Any employer interested in receiving the bulletin should so advise E.S.P.S. at 8 W. 40th St., New York 18, N.Y., and your name will be placed on the mailing list. Any engineer who is registered with the Service or wishes to register is entitled to a 35-word notice in the bulletin. Write to the New York office for forms. Your qualifications will be brought to the attention of employers on our mailing list without revealing your identity.

It is planned to extend the publication to the midwestern and western offices in the near future.

**A weekly bulletin of engineering positions open is available to AIME members at a subscription rate of $4.50 per quarter or $14 per annum; $4.50 per quarter or $14 per annum for nonmembers, payable in advance. Local offices of the Personnel Service are at 8 W. 40th St., New York 18; 57 Post St., San Francisco; and 29 E. Madison St., Chicago 1.**

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For longer roof life and reduced labor costs as a result of fewer roof changes, try TAMUL in your roofs. Contact your Taylor representative or write direct, for recommendations.

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Rare earth and yttrium metals are only a part of the wide range of LINDSAY rare earths which cover the whole gamut of rare earth technology, from crudes to highly refined materials.

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A considerable amount of interesting and revealing technical data on rare earth and yttrium metals, including detailed tabulations of properties, purities and costs, is given in our bulletins on "Rare Earth and Yttrium Metals." They will be sent to you promptly, on request.

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# personals

**Marian Balicki,** consulting metallurgist at the Knolls Atomic Power Laboratory, has been named to full membership in the New York Academy of Sciences.

**W. O. Binder,** assistant director for development of Union Carbide Metals Co., has been transferred to Union Carbide Development Co. He will maintain contact with the European steel industry, and will make Geneva, Switzerland, his headquarters.

**John B. Clark,** a research engineer, Dow Chemical Co., and **Frederick N. Rhines,** head of metallurgical research laboratory at the University of Florida, have been awarded the Henry Marion Howe Medal, the oldest honor of the American Society for Metals. The awards were presented October 18 at the Society's Annual Awards Luncheon in Philadelphia.

**Harry Czyzewski,** president of Metallurgical Engineers Inc., has been appointed by the Oregon State Board of Health to its Radiation Advisory Committee.

**Robert W. Crozier** has been appointed executive director of the Materials Advisory Board of the National Academy of Sciences-National Research Council's Division of Engineering and Industrial Research. He succeeds William J. Harris, Jr.

**Raymond F. Decker** has been named supervisor of nickel and stainless alloy research at the research laboratory of International Nickel Co. Inc.; he was formerly senior metallurgist. Dr. Decker has also been appointed to the adjunct faculty of the graduate school of the Polytechnic Institute of Brooklyn.

**Herman J. Hofmann,** service manager and in charge of advertising for J. E. Baker Co., manufacturers of dead-burned dolomite, has retired after a business career of 60 years.

**Roy S. Jamison** has been named vice president of Norwalk Powder Metals Inc.

**Martin N. Lindsay** has been made responsible for the sales of coke and pig iron for the Crucible Steel Co. of America.

**Champion H. Mathewson,** professor emeritus of metallurgy and metallography at Yale University, has been awarded the American Society of Metals' newly-established Albert Easton White Award. The award

(*Continued on page 917*)

**RESEARCH METALLURGISTS**

**The continual expansion of our central Research Laboratories offers a rich opportunity for qualified professional metallurgists, MS Ph.D. The highly diversified product line of this established, progressive corporation provides opportunity for company-sponsored metallurgical research of almost unlimited variety and scope. Personal interest, initiative, and achievement are recognized in a work environment designed to maximize individual freedom and opportunity.**

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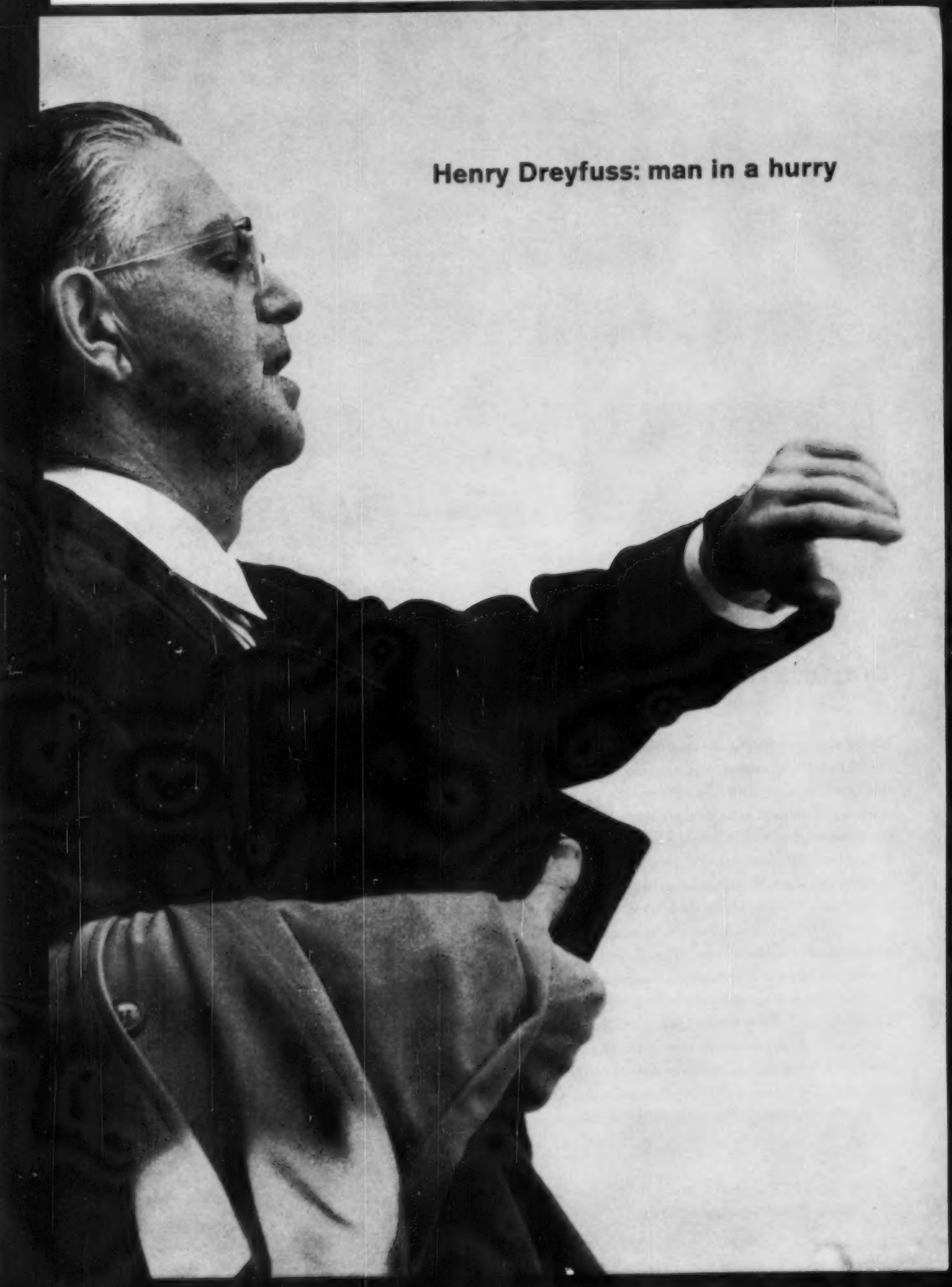
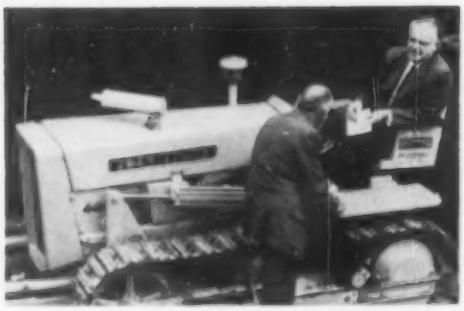


Henry Dreyfuss: man in a hurry



## Dreyfuss talks design

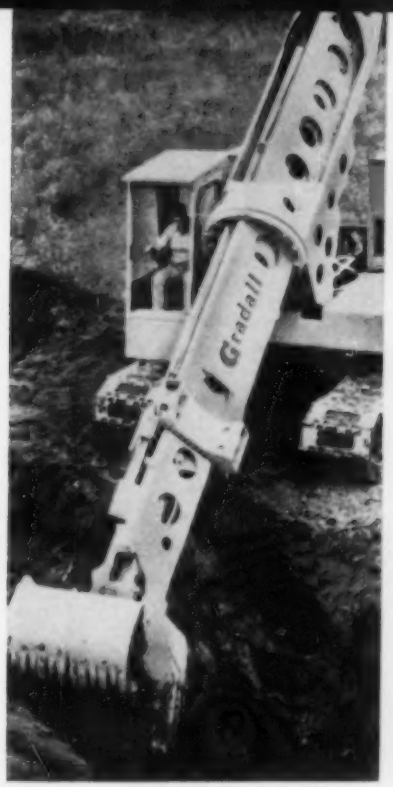
If you could get Henry Dreyfuss to sit still long enough for a caricature, the drawing would inevitably show him with his coat half on and briefcase in hand. Most likely, he would be on his way to the airport. He's on the East Coast a third of his time, on the West Coast a third, and the other third in between.

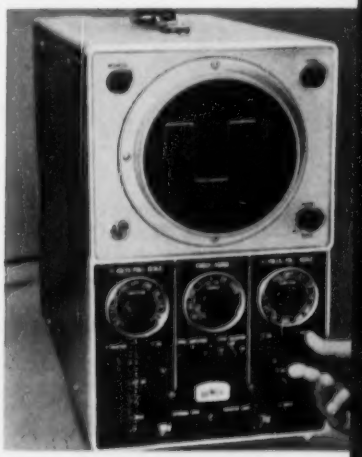
Henry Dreyfuss has been busy ever since he gave up scenery design in the late Twenties and helped pioneer the business that is now called industrial design. In the early days, he gave a new look to everything from hinges to pianos, cigarette lighters to tractors. Today he can look back on a career of redesigning vacuum cleaners and gas stations, bowling alleys and ship interiors, typewriters and dental equipment, magazine formats and military strategy rooms, plumbing fixtures and the Nike missile launcher.

But Henry Dreyfuss is not one to look back. There are designs on his boards today that will influence our lives twenty years from now. "Time," he says, "is one of the designer's big problems. A design assignment is often three years in development. The item may not be on the market for another three to ten years. After it's introduced it will be in use for any number of years. In order to design that far ahead, our ideas have to be fresh, advanced and sprightly. It is a challenge to have to think as far ahead as we do."

One thing that goes a long way is the Henry Dreyfuss design credo, and it is all about people. "It says in effect," Dreyfuss states, "that the item is going to be ridden in, sat on, looked at, talked into, operated or in some way used by people. If the point of contact between the product and people causes friction, we have failed.

"On the other hand, if people are made safer, more comfortable, more eager to purchase, more efficient, or



just plain happier—we have succeeded." And succeed Dreyfuss does, by following this yardstick for effective industrial design: 1. Safety and convenience of use. 2. Ease of maintenance. 3. Cost, including tooling, production and distribution. 4. Sales appeal. 5. Appearance.

Selection of the right material for the job plays an important role in satisfying each of the five requirements. As a matter of ethics and sheer common sense, Henry Dreyfuss, like any member of the American Society of Industrial Designers, will not endorse any one material. "We have worked with all materials. What we want is the material that is right for the job. We look for the material that combines reasonable cost with the ability to be fabricated economically, and at the same time will give the product the built-in quality and durability it needs to sell well." With no-nonsense requirements like that, it is not surprising that a great many Dreyfuss-designed products use steel in one way or another.

Steel has strength, integrity and honesty. Steel is what the designer is apt to call a 'natural.' Dreyfuss feels that the public's image of steel depends largely on the product itself. A massive steel vault door conjures up an image of strength, imperviousness. Stainless Steel tableware suggests style and modernity. Steel curtain wall panels give buildings the look of tomorrow.

The moral is this: steel has been with us for ages, yet it is the modern metal, the metal of the future. Its enduring modernity will continue to be recognized, and used, by designers like Henry Dreyfuss.

*(turn the page for a new look at steel)*

USS United States Steel

TRADEMARK

# designing with USS High Strength Steels

Good design goes beyond material selection. Once the choice has been made, the designer's job is to take full advantage of the material's properties. Few materials offer designers as much opportunity as high strength steels.

*COR-TEN Steel was developed by U.S. Steel and first used in 1933.*

USS COR-TEN Steel is a name that has become a byword in design circles. It is a time-tested, high strength low-alloy steel. Structural designers welcomed COR-TEN Steel because it allowed them to pare dead weight and to lower maintenance costs. As structures, mobile equipment and machinery got bigger and bigger, dead weight became more of a problem. Even when weight could be shaved without stress problems, durability suffered. This high strength steel answered both problems.

*Dead weight in stationary structures is costly; in mobile equipment dead weight requires more power to move.*

*USS High Strength Steels' yield points are all 50,000 psi min. compared to 33,000 psi for structural carbon steel.*

Strength did it. COR-TEN brand and other USS High Strength Steels have a 50% higher yield point than structural carbon steel. They permit as much as 33% weight reduction. They have superior resistance to atmospheric corrosion and abrasion, so there is little reason to overdesign. Their fatigue and impact properties are excellent. Here is a quick look at three well-known USS High Strength Steels:

*Send for the manual described at the right for a comprehensive guide on how to design with high strength steels.*

USS COR-TEN Steel has a yield point 50% greater than structural carbon steel, has four to six times its resistance to atmospheric corrosion. It is used to do any one of these three things: 1) in slimmer sections to cut weight at no strength loss; 2) in equal sections to increase load-carrying capacity, cut maintenance and lengthen life; and 3) any number of combinations of 1 and 2. COR-TEN Steel also has greatly superior paint adherence and is used where a longer interval between repainting is wanted.

USS TRI-TEN Steel, with its 50% higher yield point than structural carbon steel, has superior notch toughness at low temperatures and keeps rugged equipment operating even in sub-zero weather. Its high endurance limit makes TRI-TEN Steel ideal for mobile equipment that must take repeated loading and reversals of stress. It is a natural for welded structures and bridges.

*MAN-TEN Steel costs only about 20% more than structural carbon steel; TRI-TEN Steel about 36% more, and COR-TEN Steel 42% more.*

USS MAN-TEN Steel also has a 50% higher yield point than structural carbon steel, and is the low-cost member of the family. Weight reduction as little as 17% with MAN-TEN Steel will save money on material cost alone. MAN-TEN Steel is a tough, durable steel and widely used in earthmoving equipment, truck frames, material handling apparatus and riveted bridges.

**High strength steels represent but a few of the over 3000 grades of steel in existence today. United States Steel makes a complete line of high strength steels, as well as constructional alloy, stainless and carbon steels. Bring your design problems to us. United States Steel, 525 William Penn Place, Pittsburgh 30, Pa.**

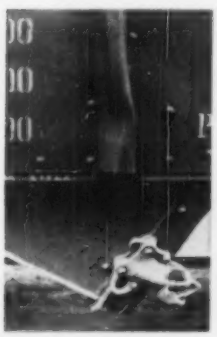
*USS, COR-TEN, MAN-TEN and TRI-TEN are registered trademarks.*

USS United States Steel

Cranes have to operate in all-weather temperatures and are subject to stress and shock. That's why many of them are made of tough TRI-TEN Steel.

Light standards stay good looking for years because of COR-TEN Steel's outstanding atmospheric corrosion resistance. Paint life is extended. Slim design is made possible by COR-TEN Steel's strength.

TRI-TEN Steel has cut weight and cost of dozens of major bridges. In the bridge shown here, TRI-TEN Steel saved a quarter of a million dollars.



One of the first applications of COR-TEN Steel was in hopper cars for weight reduction and longer life. Today, use of COR-TEN Steel can save hundreds of dollars over the life of a car.

MAN-TEN Steel, used in truck frames and body members, reduces dead weight and increases payload.

The LPG cylinder business uses considerable amounts of MAN-TEN Steel because of its strength, cost and ease of fabrication to lighten the weight.

This mark tells you a product is made of modern, dependable Steel.

Here's a book that is in the hands of thousands of engineers and designers. It is your guide to the design of lighter, stronger equipment and structures.

# design manual for high strength steels

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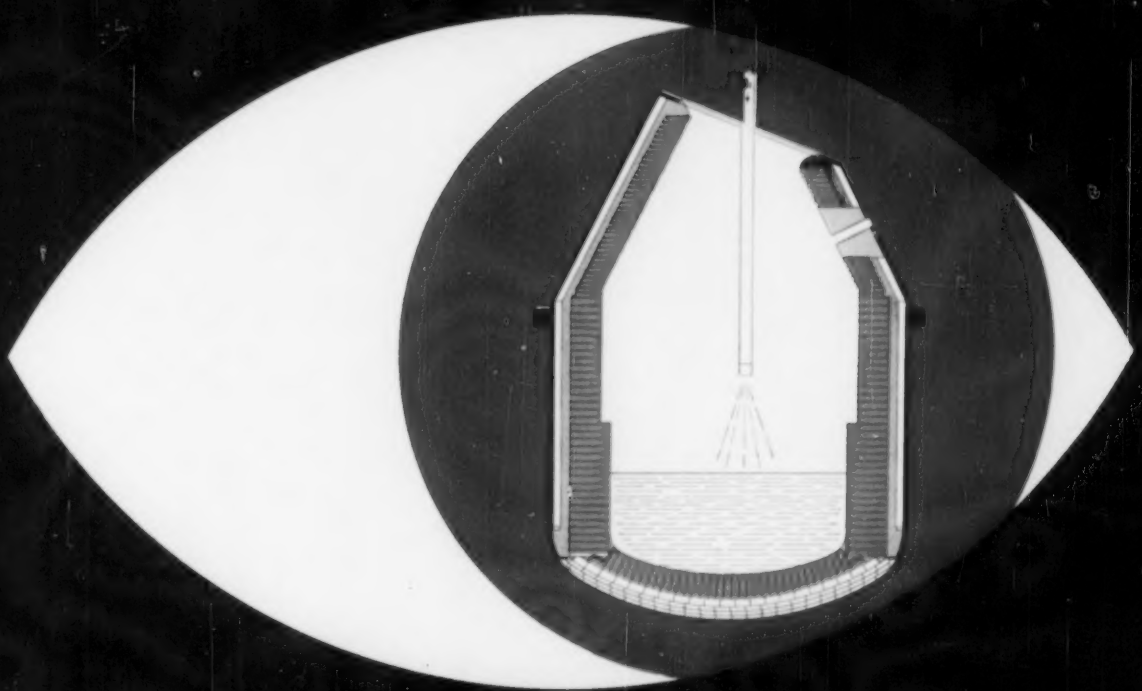
# capacability

Basic reflects *Capacability* . . . the *capacity* to manufacture and deliver quality refractories — the *ability* of talented and creative people to do a better job through vision, resourcefulness and skill. With capacability, Basic continues to develop and furnish steelmakers a complete line of better hearth lining and maintenance materials — dead-burned dolomites; ramming, gunning and patching refractories; and tar-bonded linings for the new oxygen furnaces.

**basic incorporated**

HANNA BUILDING
CLEVELAND 15, OHIO

# *Tarblok* and *Tarmix*...better basic oxygen furnace linings



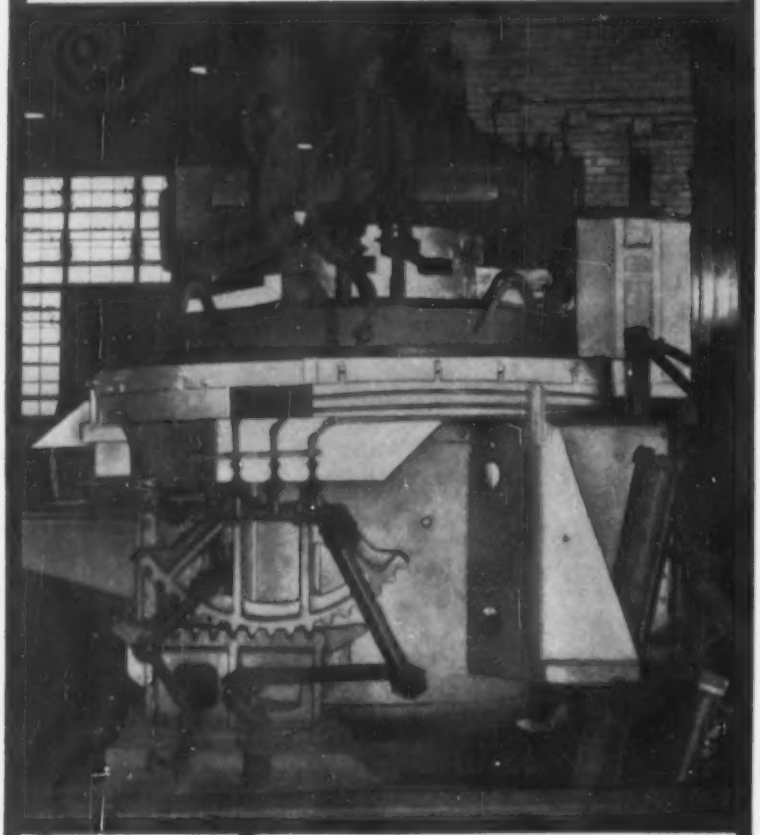
When it comes to producing better linings for oxygen steelmaking furnaces, *Capacability* is a must! And, *capacability* is Basic; in development, production, application.

In the early 1950's, Basic—envisioning acceptance in this country of the basic oxygen furnace—studied every operating unit in the free world. A development program was then launched to produce superior refractory linings for these furnaces. It was only natural that in 1954 the first U. S. oxygen steel producer looked to Basic for furnace refractories. We were ready. Today Basic is the only integrated manufacturer of tar-bonded oxygen furnace linings—shipping to virtually every oxygen steelmaker in the Western Hemisphere.

Basic's tar-bonded refractories, TARBLOK and TARMIX, are manufactured to exacting specifications. Produced in a special plant adjacent to the company's Maple Grove, Ohio works, both TARBLOK and TARMIX compositions are comprised primarily of dead-burned dolomite from this completely integrated facility and/or dead-burned magnesite from Basic's Gabbs, Nevada plant. These facilities enable precise control of physical and chemical properties of tar-bonded refractories.

In the challenging decades ahead, Basic will continue to pioneer better lining and maintenance materials for oxygen steelmaking through its experience, vision and skill—through its *Capacability*.

## CONTROL ELECTRIC FURNACE FUMES



**Pangborn offers a new concept in electric furnace exhaust hoods!**

After years of development, Pangborn now offers effective control of smoke, fumes and dust from electric melting furnaces with minimum interference to furnace operations and maintenance. The hood design is based on the fundamental dust control principle of confining and capturing fumes and dust immediately adjacent the source. Effective control is secured with substantially reduced exhaust air volumes.

The Pangborn Exhaust Hood reduces the weight carried by the furnace roof; reduces hood areas subject to high temperatures; reduces electrode travel limitations and is applicable to top and side charge furnaces of all types and sizes.

With the exhaust hood connected to an efficient Pangborn Cloth Bag Collector, compliance with the most rigid air pollution control regulations is assured. For information call the Pangborn man in your area or write: PANGBORN CORP., 500 Pangborn Blvd., Hagerstown, Md. *Manufacturers of Blast Cleaning and Dust Control Equipment.*

**Pangborn CONTROLS DUST**


# new books

Books that are marked (•) may be ordered through AIME. Address Irene K. Sharp, AIME Book Dept., 29 W. 39 St., New York 18, N. Y. A discount is given whenever it is possible.

**The Surface Chemistry of Metals and Semiconductors,** edited by Harry C. Gatos, John Wiley & Sons, Inc., 526 pp., $12.50, 1960—This volume contains the papers presented at the 1959 symposium co-sponsored by the Electrochemical Society and the Office of Naval Research. Contributors from France, Germany, Australia, and the US are represented. All 22 papers are in English. The material is grouped in five parts: chemistry and physics of surfaces, imperfections and surface behavior, electrode behavior of metals and semiconductors, surface reactions in liquid media, and surface reactions in gaseous media. •

**Lead Isotopes in Geology** by R. D. Russell and R. M. Farquhar, Interscience Publishers, Inc., 243 pp., $9.00, 1960—This monograph is concerned with the isotopes of lead. The introduction discusses briefly isotopic abundance variations, lead ores and minerals, and the decay of uranium and thorium to lead, without developing in detail the dating of uranium and thorium. Succeeding chapters discuss measurement of lead isotope ratios, methods of measuring the age of the earth by physical, lead isotope, and lead-uranium-thorium methods, the dating of galenas by means of their isotopic constitution, anomalous leads, and extensions of the Holmes-Houtermans model. The authors draw mainly on their own views, but attempt fair treatment of other scientists' results and interpretations. •

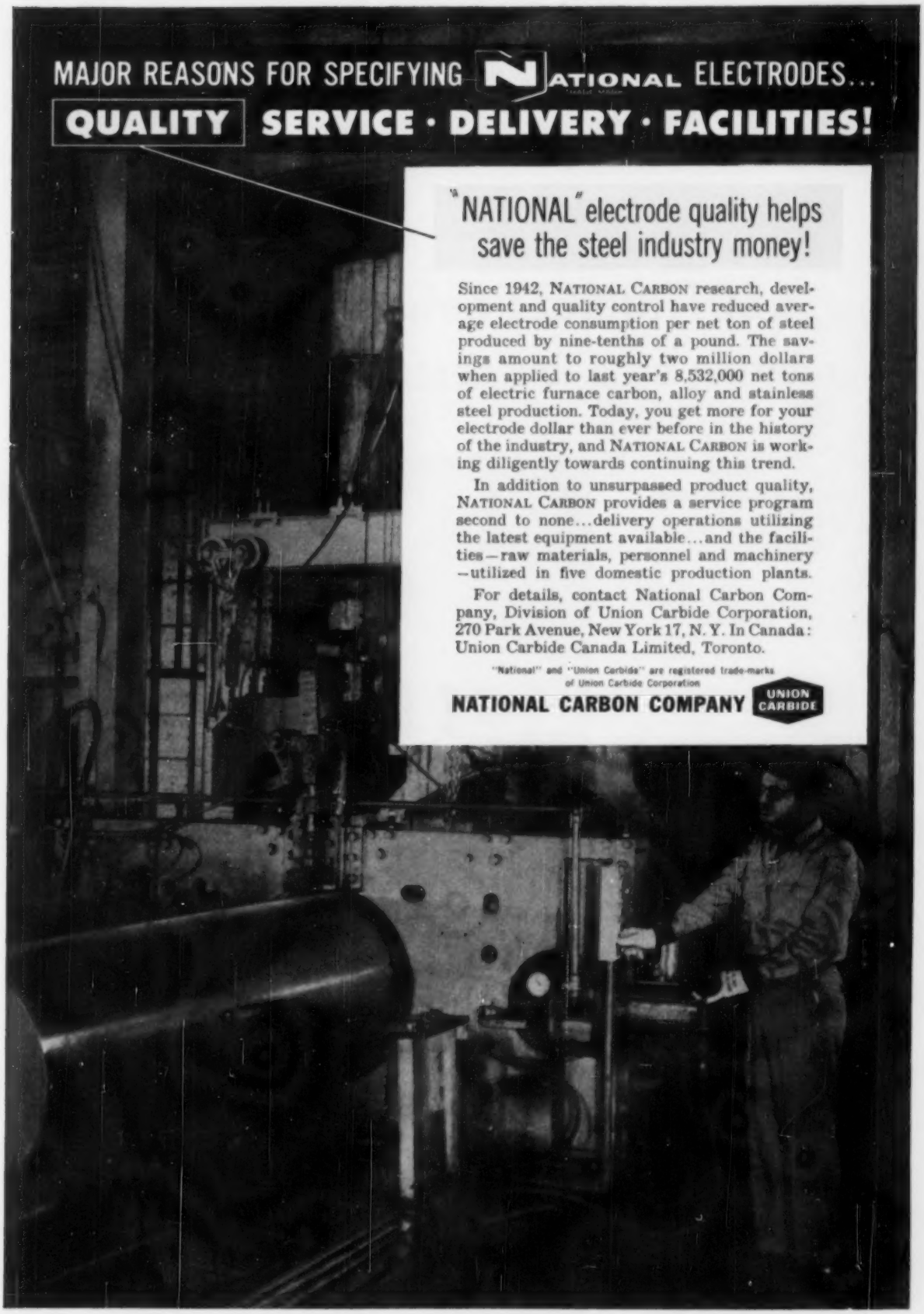
**ASM Review of Metal Literature,** 1959, edited by Marjorie R. Hyslop, American Society for Metals, 1266 pp., $20, 1960—The 16th annual collation of the monthly annotated survey of articles, technical papers, and reports dealing with the technology of metals, appearing in engineering, scientific, and industrial journals and books here and abroad, prepared at the Center for Documentation and Communications Research, Western Reserve University, Cleveland. •

**Metallic Corrosion Inhibitors,** by I. N. Putilova and others, Pergamon Press, Incl., 196 pp., $10, 1960—A translation of a Russian monograph intended to systematize and generalize available information on the theory and practice of applying corrosion inhibitors. General theoretical

(*Continued on page 969*)

MAJOR REASONS FOR SPECIFYING NATIONAL ELECTRODES...

QUALITY SERVICE · DELIVERY · FACILITIES!



"NATIONAL" electrode quality helps save the steel industry money!

Since 1942, NATIONAL CARBON research, development and quality control have reduced average electrode consumption per net ton of steel produced by nine-tenths of a pound. The savings amount to roughly two million dollars when applied to last year's 8,532,000 net tons of electric furnace carbon, alloy and stainless steel production. Today, you get more for your electrode dollar than ever before in the history of the industry, and NATIONAL CARBON is working diligently towards continuing this trend.

In addition to unsurpassed product quality, NATIONAL CARBON provides a service program second to none...delivery operations utilizing the latest equipment available...and the facilities—raw materials, personnel and machinery—utilized in five domestic production plants.

For details, contact National Carbon Company, Division of Union Carbide Corporation, 270 Park Avenue, New York 17, N. Y. In Canada: Union Carbide Canada Limited, Toronto.

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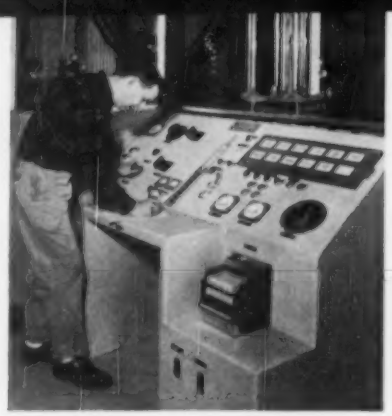
NATIONAL CARBON COMPANY UNION CARBIDE



*Simplified controls centralize recording, indicating and monitoring of all melting parameters to ensure effective and consistent operation.*

# Now–**LECTROMELT** furnaces put vacuum melting on a low-cost production basis

## *Automatic operation, 20 minute loading time, sturdy design contribute to unequalled economy*

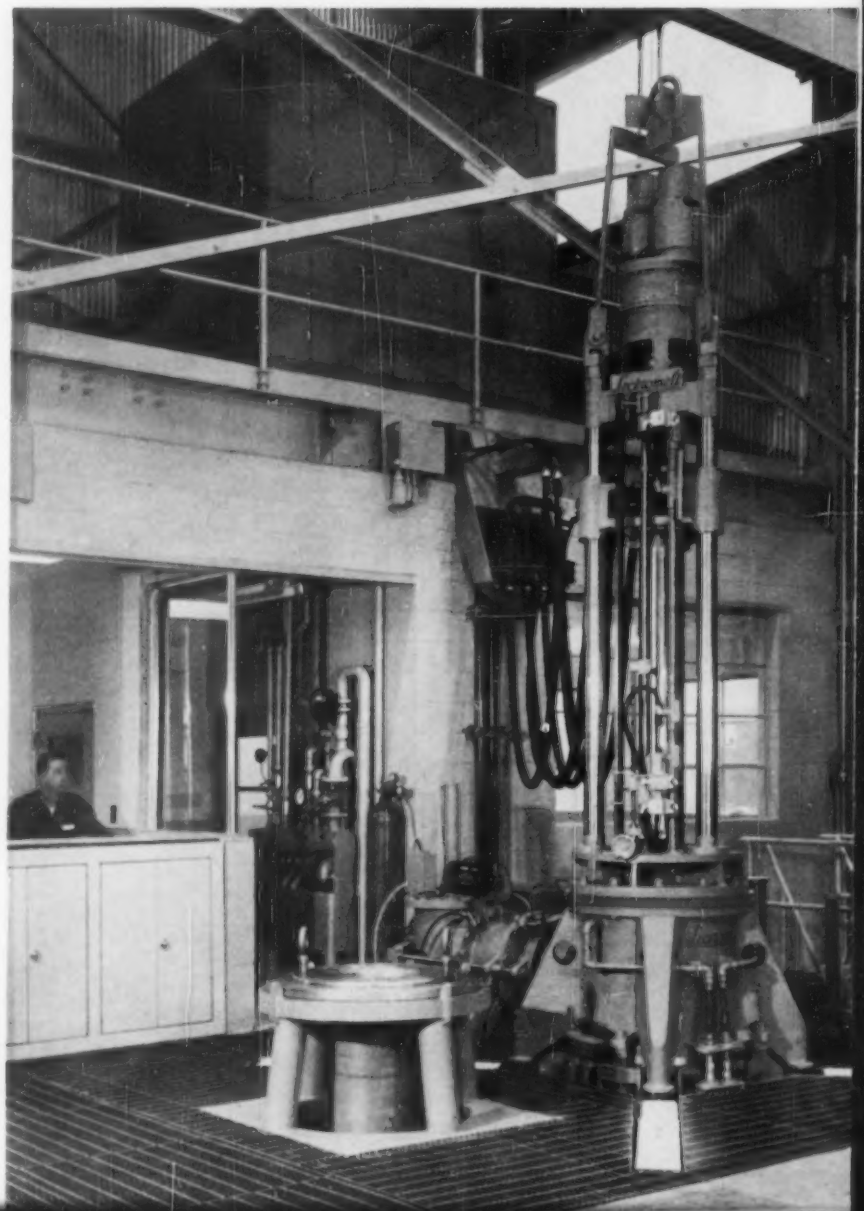
LECTROMELT vacuum arc melting furnaces are based on years of production experience in vacuum melting, plus extensive knowledge of the design, fabrication, and installation of melting furnaces for maximum production with minimum cost. Several recent installations are routinely melting a wide range of steels at a cost far below that thought of as minimum just a few years ago. Consumable electrode furnaces with melt capacities of less than 50 pounds to more than 40 tons are now available as production units.

All operating functions, including electrode and ingot handling, are performed at a single level. Three men can effectively handle two furnaces, since the highly efficient electrode control system requires minimum attention during melting, and manual operations are a minimal part of the cycle. Typical of the many advanced design features is a new electrode clamp that helps reduce turn-around time to just 20 minutes.

LECTROMELT's vacuum furnace department is staffed to handle your melting problems from concept to production. For further details please call or write: LECTROMELT Furnace Division, McGraw-Edison Company, Vacuum Furnace Department, P.O. Box 1257, Pittsburgh 30, Pa., GRant 1-8782.

**Lectromelt**®

McGRAW EDISON



*Over eight million pounds of steel have been produced by the Latrobe Steel Co. using this 20-inch furnace that melts 8500-pound ingots. The melt shop and vacuum furnace—designed and built by LECTROMELT in less than seven months—have a trouble-free record. The shop can be expanded to four furnaces.*

### New Ti alloy

A new creep-resistant alloy, extending titanium's useable strength in jet engines to 900°F, has been introduced by Titanium Metals Corp. of America. Development data prompted incorporation of the Ti-8Al-1Mo-1V alloy into preliminary designs of several advanced military jet engines. This new alloy exhibits a high modulus:density ratio, and because of its relatively high aluminum content, has a lower density than unalloyed titanium and most available titanium alloys. It can be readily forged, and its room-temperature tensile properties are comparable to Ti-6Al-4V, which has accounted for more than half of all titanium sold to date.

### Mo single crystals

Large single crystals of molybdenum, approx 18 in. long by 1 x 3 in. cross section have been grown by the Wah Chang Corp. at Albany, Ore. Quadruple electron beam melting achieved high purity material with a total interstitial level below 40 ppm. From the single crystals, sheets approx 3 x 12 in. x 0.050 in. thick have been produced and will be further reduced to 0.010 in. thickness. Single crystals of other materials, specifically tungsten, can be grown in the same matter and will form the basis of X-ray, recrystallization, transition temperature, and anisotropic studies.

### Iron beneficiation process

A new process for iron ore beneficiation has been placed in operation at the Humboldt Mich., plant of Humboldt Mining Co.—jointly owned by Cleveland-Cliffs Iron Co. and Ford Motor Co. The $15-million plant has capacity for 650,000 tons per year of pelletized concentrate. It will produce 60 to 62 pct iron from previously unusable Jasper hematite ore containing 30 to 35 pct iron. Ford is expected to use a large share of the output.

In the new process, the ore, after being crushed and ground to a fine powder, is sent through a flotation process to separate usable ore from gangue. The floated material is agglomerated and heat treated using Grate-Kiln equipment developed and manufactured by Allis-Chalmers. The Grate-Kiln system is an integrated combination of a traveling chain grate and a rotary kiln which has been used in making cement and processing limestone, but this is the first time it has been applied to agglomerate iron ore. The last operation induces grain recrystallization to yield a high-strength pellet. Further developments are under way to produce self-fluxing pellets by combining limestone with the iron ore concentrate. Advantage of the pellet form is increased blast furnace capacity, reportedly as much as 30 to 50 pct.

### V from slag

Two firms—Minerals Engineering Co. and Susquehanna-Western, Inc.,—have formed a joint venture to produce vanadium pentoxide near Salt Lake City. An entirely new process will be employed to chemically extract vanadium from vanadium-bearing slag, a heretofore wasted by-product of western phosphorus operations.

### New missile steel

*Rocoloy 270*, a new low-alloy, high-strength steel, may double the range of the Polaris missile in the near future. The alloy, developed by the Mellon Institute, has a yield strength of 270,000 psi and an ultimate strength of approx 325,000 psi, and is as much as 50 pct stronger than steels presently used in the Polaris. A spokesman for the institute stated that, by using the new alloy, fabricators could cut the thickness and weight of a missile motor case in half. The chief alloying elements which do not exceed 8 pct in total are chromium, molybdenum, tungsten, nickel, and cobalt. Thus far, the alloy, produced by consumable electrode melting, has not been tested in a missile, but it has been used to fabricate test vessels of 6, 12, 18, and 28 in. diam.

### Northwest Strategic-Udy plant

Webb & Knapp Inc., of New York, contracted the Bonneville Power Administration to supply electric power for a new type of steel mill at Anaconda, Mont. The plant, which will be the largest steel producing facility in the Northwest, will use the new Strategic-Udy process to produce steel from iron contained in discarded copper slag at the Anaconda Company's smelter. The $30 to $40-million plant will have an annual capacity of 350,000 tons, and may be the first plant in the US to use the new process. [See p. 829 JOURNAL OF METALS, Dec. 1959.]

### Uranium developments

Uranium mononitride, uranium sulfide, and uranium silicides are potential reactor fuels which show the most promise, according to a Battelle Memorial Institute report to the American Society for Metals-Atomic Energy Commission Joint Conference in Philadelphia during October.

Critical evaluation of all uranium compounds provided a basis for the selection of the compounds which showed the greatest returns per research and development dollar invested. Compounds, such as uranium dioxide and uranium carbide, were mentioned as having the greatest current potential because of the advanced state of their technology.

Herbert S. Kalish of the Metallurgical Laboratories of Olin Mathieson Chemical Corp., announced that the company is developing an economic method for fabricating uranium carbide on a production basis. The compound shows promise of becoming an important nuclear fuel because of its high uranium density, good thermal conductivity, and good irradiation stability, but its future will ultimately depend upon economic evaluation and the ability to control the composition within the desired limits.

W. R. Grace & Co.'s Davison Chemical div., announced that it will undertake purification of $U_{nat}$. The operation, which requires remote control, will be the first of its kind to be performed on a commercial basis in private industry anywhere in the world.

REPORTER

REPORTER

### X-ray controlled sinter

Youngstown Sheet & Tube Co. has recently installed an X-ray device to analyze the content of five elements in iron ore sinter. The on-line X-ray analysis is expected to provide greater predictability of the sinter product. The device will provide for chemically uniform proportioning on the basis of the weight of these elements in the ore and those additive elements which are important to the sintering process. The equipment can control the incoming flow of materials to a line, the degree and quality of finished mixes and blends, and the composition of end products. The X-ray analyzer is not yet used on a production basis, but evaluation tests indicate such an application in the near future.

### Last open hearth shops—USSR?

A new six-furnace shop with an annual capacity of 3.5 million tons is being planned by Moscow engineers. Each of the four large furnaces—850 to 950 metric tons—will melt 650,000 to 750,000 tons of steel annually. Labor productivity is expected to be at least 25 pct higher than for shops equipped with 500-ton furnaces. Also expected is a 2.5 to 3 pct reduction in costs.

At Cherepovets, a large new open hearth furnace has been installed, and another six are scheduled for completion before the end of the year.

### Easier $U_{235}$

A relatively cheap method of producing fissionable material—eliminating costly diffusion plants—could conceivably put atomic war materials within reach of the smaller countries now not included in the exclusive nuclear club of the US, the UK, the USSR, and France. The process utilizes centrifugal force to separate $U_{235}$ from heavier $U_{238}$ in uranium hexafluoride gas, instead of the diffusion method now commonly used. Atomic sources said that a small country like Cuba in time could use the new method to put together a crude nuclear weapon at a cost of not much more than $50,000,000.

Professor Wilhelm Groth of Bonn University, who took part in the development of the new method, stated that existing centrifuges require only one-tenth as much electric power as a diffusion apparatus of the same capacity. Increases in yield capacities, already in sight, will eventually enable the centrifuge process to compete economically with gaseous diffusion methods for making nuclear fuels utilized in atomic power plants.

### Oxygen for Cu smelting

A series of plant-scale experiments using oxygen in the smelting of copper is planned by the Kennecott Copper Corp. Contracts for $750,000 in pilot-plant equipment to be installed at the Garfield smelter follow the successful conclusion of work at Kennecott's research center and the Chino division.

Some earlier thoughts on the possibilities of using oxygen in the smelting of copper are found on pp. 533-537, JOURNAL OF METALS, Aug. 1958.

### USSR—Oxygen and electric

The Soviets are also expanding their electric furnace facilities. A new electric steel shop was scheduled to start operation at Chelyabinsky in mid-November.

At the Petrovskiy works, Dnepropetrovsk, oxygen steel is reportedly being made in a new type of converter, permitting 40 to 50 more melts to be made than previously.

### Rapid heat treater

A new concept in heat transfer equipment design that reduces heating time by 85 pct has been introduced by General Electric Co. The rapid heat transfer is made possible by utilizing a fluidized bed of fine refractory particles suspended and agitated by gas flow through a porous plate. Thermal coefficients run as high as 130 Btu per hr per sq ft per F. These fluidized solid particles have virtually the same physical and thermal properties as a true liquid; however, they are inert and will not wet, abrade, or otherwise affect the equipment or work according to GE engineers. Because of its versatility, the batch type furnace can be used for either heating or cooling operations, and future plans include possibilities for carburizing, carbonitriding, and nitriding.

### Beryllium

The Mexican Government has granted Beryllium Resources Inc. the rights to explore for, develop, mine, and concentrate beryllium minerals on a cost-plus basis. Beryllium Resources Inc. is owned jointly by Federal Resources Corp. and the Hidden Splendor Mining Co., subsidiary of the Atlas Corp.

At the same time, it was reported that Dynamic Metals Corp.—also controlled by Hidden Splendor and Federal Resources—is proceeding with the perfection of a flotation reagent capable of floating beryllium-bearing minerals.

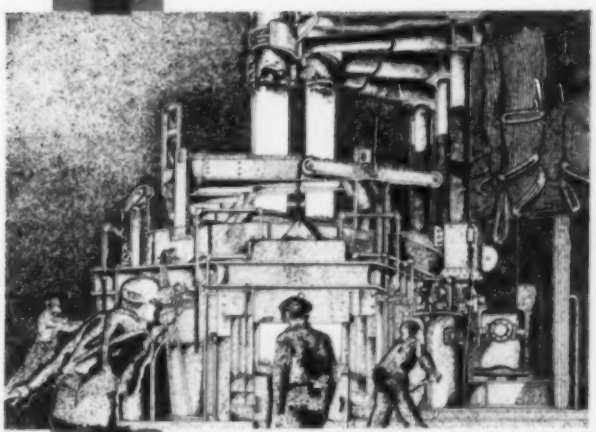
The Mexican Government's agreement and another pact with Brush Beryllium Co. provide that, when Beryllium Resources has established adequate ore reserves, Brush will join it in constructing, designing, and operating a new extraction plant in Mexico.

### . . . find Utah ore body

Vitro Minerals Corp. has announced the discovery of a significant beryllium deposit in the Topaz Mountain area of Utah, about 150 mi from Salt Lake City. The ore is said to be in disseminated, non-pegmatitic deposits—much of it close to the surface where it can be mined by open-pit techniques. Studies indicate that the ore is readily soluble in sulfuric acid and is apparently amenable to conventional hydrometallurgical processing.

Petrographic and mineralogical studies by Vitro geologists uncovered a new beryllium mineral in the ore. They have dubbed it *vitroite*. Laboratory studies on the economics of processing the mineral currently are being carried out at the Co.'s uranium plant at Salt Lake City.

# AN ELECTRODE'S HIDDEN VALUES EXCEL IN REDUCING MELT-TON COSTS



One electrode looks much like another—yet one will do the job economically while another can be the cause of costly trouble. Efficient performance and reduction of down-time are directly related to an electrode's hidden values.

These values grow out of unceasing research that leads to steady product improvement—out of the unwavering control of quality—and out of customer service that renders immediate assistance in overcoming abnormal operating problems.

Such hidden values find further expression in the substantial inventories maintained for customer convenience—in the rapidity of shipment and delivery—and in the integrity of the maker in providing products that can be fully trusted.

These are the values you get in full measure—in addition to the intrinsic merit of the product—when you specify GLC electrodes.

PRODUCTS ELECTRODE GLC DIVISION YOU CAN TRUST

**GREAT LAKES CARBON CORPORATION**

18 EAST 48TH STREET, NEW YORK 17, N. Y.

## SECTION GOALS TO GO

**Amounts Still to Be Raised by Various Sections to Attain Goals and (in parentheses) Percentage of Section Members That Have So Far Contributed (November 9, 1960)**

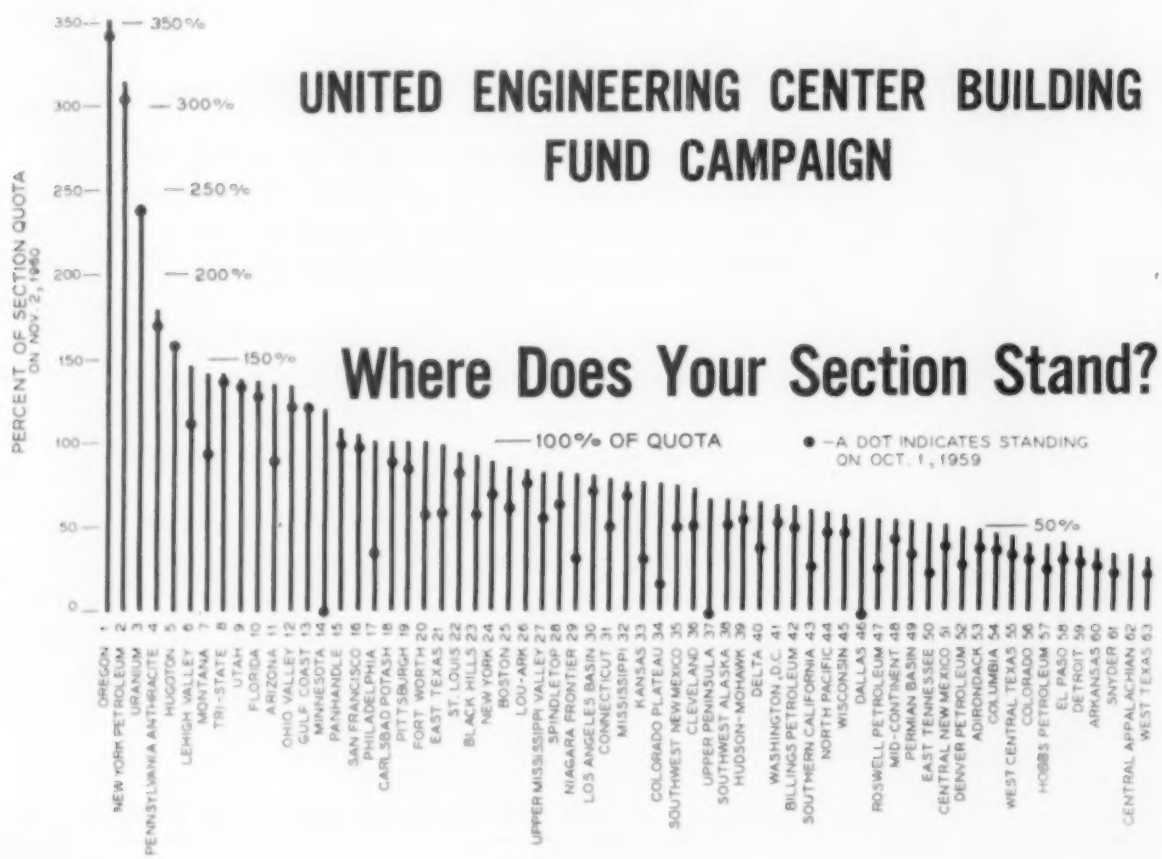
| Section | Amount | Section | Amount |
|---|---|---|---|
| New York (30) | $14,801 | Hobbs Petroleum (20) | $852 |
| Chicago (10) | 7,164 | East Tennessee (12) | 819 |
| Oklahoma City (2) | 5,746 | Upper Peninsula (40) | 714 |
| S.W. Texas (16) | 5,394 | South Plains (38) | 699 |
| Mid-Continent (34) | 5,037 | Carolinas (4) | 685 |
| Dallas (33) | 4,082 | Connecticut (24) | 664 |
| North Texas (1) | 3,915 | Four Corners (24) | 660 |
| Permian Basin (27) | 3,556 | California Coastal (10) | 655 |
| Colorado (9) | 3,050 | Colorado Plateau (23) | 643 |
| Central Appalachian (7) | 2,770 | Billings Petroleum (54) | 635 |
| Evangeline (15) | 2,764 | Hudson-Mohawk (34) | 567 |
| Delta (33) | 2,752 | Boston (37) | 561 |
| Illinois Basin (5) | 2,700 | Wisconsin (19) | 553 |
| Balcones (7) | 2,649 | Spindletop (41) | 521 |
| Detroit (9) | 2,490 | Arkansas (13) | 506 |
| Southern California (13) | 2,437 | Utah Coal (4) | 480 |
| Southeast (20) | 2,366 | Wyoming Mining & Metals (18) | 480 |
| Denver Petroleum (31) | 2,227 | Niagara Frontier (20) | 457 |
| Nevada (4) | 2,175 | Snyder (34) | 435 |
| Washington, D. C. (26) | 2,068 | Kansas (25) | 421 |
| San Joaquin Valley (12) | 2,035 | Williston Basin (32) | 420 |
| Columbia (19) | 1,968 | Lou-Ark (45) | 415 |
| Wyoming Petroleum (27) | 1,823 | Northern Oklahoma (0) | 375 |
| Los Angeles Basin (22) | 1,724 | Alaska (5) | 329 |
| Cleveland (14) | 1,493 | St. Louis (12) | 286 |
| El Paso (22) | 1,287 | Mississippi (59) | 266 |
| West Central Texas (40) | 1,271 | Roswell Petroleum (46) | 250 |
| North Pacific (20) | 1,215 | S.W. Alaska (42 ) | 243 |
| Appalachian Petroleum (31) | 1,060 | S.W. New Mexico (36) | 200 |
| Great Bend (15) | 1,020 | Black Hills (35) | 72 |
| Adirondack (26) | 879 | Upper Mississippi Val. (48) | 50 |
| Central New Mexico (14) | 863 | East Texas (52) | 28 |

*Of the Sections that have attained their goals, the following list shows the percentage of members that have contributed:*

| Section | Percent | Section | Percent |
|---|---|---|---|
| Oregon | 58 | Ohio Valley | 27 |
| New York Petroleum | 23 | Gulf Coast | 59 |
| Uranium | 41 | Minnesota | — |
| Pennsylvania Anthracite | 42 | Panhandle | 72 |
| Hugoton | 76 | San Francisco | 16 |
| Lehigh Valley | 44 | Philadelphia | 24 |
| Montana | 40 | Carlsbad Potash | 69 |
| Tri-State | 49 | Pittsburgh | 29 |
| Utah | 25 | Fort Worth | 56 |
| Florida | 22 | | — |
| Arizona | 40 | Average 19 Sections | 43 |


# Our Faces Are Still Red!

The most ambitious joint activity of the engineering profession is approaching completion. Construction of the new United Engineering Center is proceeding rapidly. The industry drive to raise funds for this Center has produced approximately $5 million dollars. Voluntary contributions from members of all participating engineering societies exceed $3

million. BUT—almost $1 million remains to be pledged. It is hoped that this can be achieved before the end of the year, either in payments or pledges that can be paid over the next three years at the members' convenience.

### AIME LAGS

Among the Founder Engineering Societies, *your* professional Society—AIME—lags on a percentage basis, with $84,000 still to be pledged of its quota of $500,000. Nearly 20,000 of our members are yet to be heard from. Are *you* one of these? It is important to get this job done this year. Checks should be made payable to United Engineering Trustees and are tax-deductible—or you may pledge now and pay later.

### Where We Stand

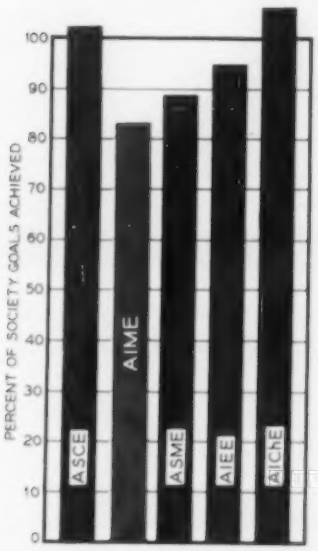
AIME Local Sections have been advised that returns from members who have made pledges should be completed by Dec. 31, 1960. Twenty Local Sections have now (November 9) attained their goals, and 34 others have less than $1000 to raise, as shown by the table at the left. This table also shows that in the Sections that have met or exceeded their quotas, an average of 43 pct of their members have contributed, whereas of the 41 Sections that have $640 or more to raise, only 17 pct of their membership has pledged. Inasmuch as the chart and table show that acceptance of professional responsibilities, and generosity in supporting a most important cause, are not matters of geography among our members, it seems evident that, for the most part, members in the lagging Local Sections have not been personally approached.

### What You Can Do

If your name is conspicuous by its absence from the list, you can remedy this before the end of December by sending in your pledge to your Local Section Chairman or Secretary, without further solicitation. And, better yet, offer to help your Section officers in raising the necessary money to meet the Section's quota. A few personal calls, or phone calls, are all that are necessary for many of the Sections to attain their targets.

The United Engineering Center, housing AIME headquarters, is being erected to serve you. When it is completed, you will be proud to know that you have contributed.

## How is AIME Doing?




*United Engineering Center Building Fund Member-Gifts Campaign, Society Status as of Nov. 1, 1960.*

*Work is progressing nicely on the new United Engineering Center as can be seen below. AIME will occupy the 13th and 14th floors of the building located at United Nations Plaza and 47th St. in New York.*

# Another is with CORHART REFRACTORIES

## CORHART PROVES IT IN THE HOT SPOTS!

MAKESHIFT facilities and cheap labor keep Communist China's cost per ton of steel low. But in America *increased operating efficiency* is the best way to keep costs down.

Corhart Electrocast Refractories are one important source for *permanent reductions* in the cost of operating steel melting furnaces. Electrocast refractories are electrically-melted and offer up to double the life of other basic refractories.

Take a close look at the troublesome wear areas in your furnace — the "hot spots" which cause premature repair shutdowns. Corhart Electrocast refractories can effectively reinforce these areas and balance the total refractory life of a furnace. By installing Corhart in just these areas, many open hearth and electric furnace operators have increased furnace life, measurably cutting refractory cost per ton of steel produced.

With Corhart Electrocast Refractories you are, in effect, paying a little more for small refractory areas to assure greater *overall* furnace efficiency. For more information on Corhart Electrocast write: Corhart Refractories Company, Incorporated, 942 Commonwealth Building, Louisville 2, Kentucky.

*CORHART PROVES IT IN THE HOT SPOTS!*

QUALITY ECONOMY ENDURANCE

**CORHART REFRACTORIES COMPANY**

**A subsidiary of Corning Glass Works**

The words "Corhart", "ZAC", and "Electrocast" are registered Trade Marks which indicate manufacture by Corhart Refractories Company, Incorporated

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| J. D. Hanawalt | T. A. Read |
| J. J. Harwood | A. J. Shaler |

V. F. Zackay


# editorial

## *We Tried!*

As in past years, the December issue of the JOURNAL OF METALS is devoted to the annual AIME Electric Furnace Conference. And included within these covers is the official program for the conference, as well as information on the Electric Furnace Committee itself. There are also a number of articles in this general area of metallurgy.

Traditionally, it has been our aim to bring to our readers in this issue what appeared to be the most outstanding papers scheduled to be presented at the Electric Furnace Conference. But this year, as in past years, we have largely been unable to fulfill this objective, because the majority of papers were not prepared in time to make our publication deadline.

With emphasis on the electric furnace in this issue, we feel that several months should pass before again turning to this field in order to provide our readers with articles in other areas of specialization. This means that electric furnace papers are either published in December or else they must wait until sometime well into the following year.

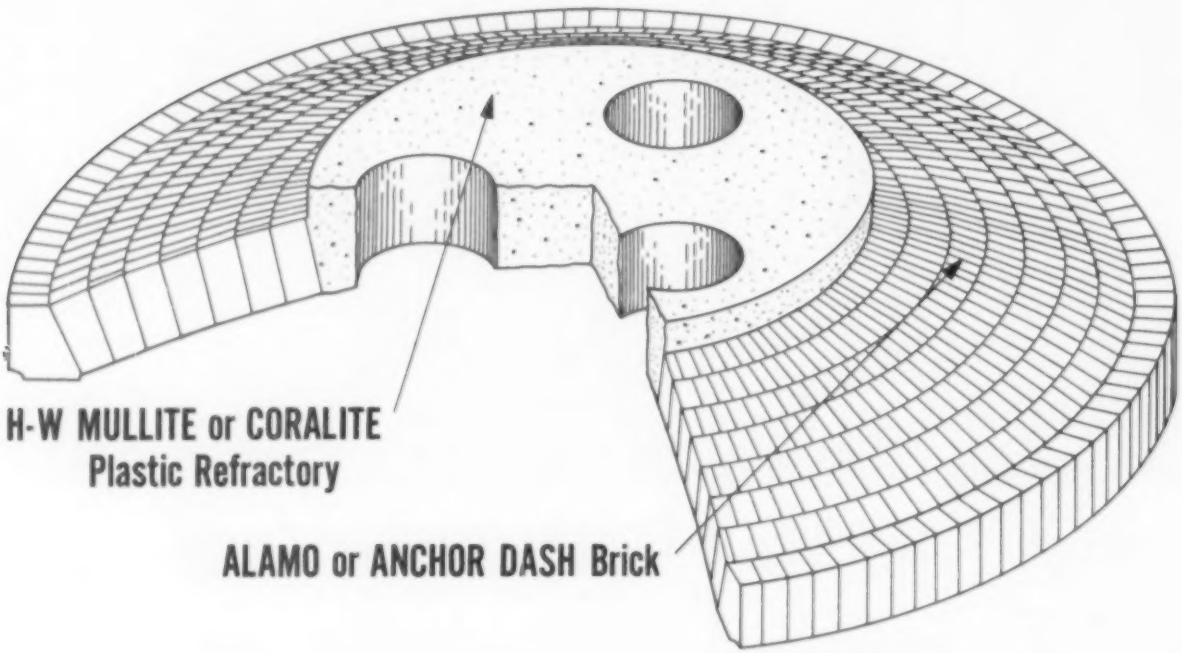
But this situation is not confined to this one conference, and exactly the same problem emerges at the time of the blast furnace and the open hearth conferences.

So, to program chairmen, authors, and those actively engaged in organizing these and other conferences, we would ask your help in encouraging everyone presenting a paper to forward a copy to The Metallurgical Society office or the JOURNAL OF METALS' office at least six weeks prior to the conference. In this way you can help us to do a better job in bringing to you the most vital and up-to-date information in your field when you want it.

Thank you. FWS

# ELECTRIC FURNACE ROOF LIFE IMPROVED

## with combination Harbison-Walker Monolithic and Brick constructions




In electric steelmelting furnaces, roof life in comparison with that of the walls and bottom is very important in the overall furnace economy. The center section of the roof is exposed to the most severe treatment, costs most to install in time and money and is most difficult to build with the best workmanship.

When temperatures and other factors of operation and construction exceed those for which silica brick serve best, Harbison-Walker superduty fireclay and high-alumina brick are selected to provide the needed margin of durability for best results.

H-W MULLITE PLASTIC REFRACTORY and CORALITE PLASTIC REFRACTORY used for the monolithic center sections are physically and chemically compatible with these classes of brick and by fortifying this portion of the roof, the best balance in service life is achieved. These plastic refractories possess the most desirable working properties for easiest installation with freedom from forming defects. At operating temperatures, a strong ceramic bond with negligible volume change is developed. Other properties which contribute to their exceptional durability are high density with low permeability and unusually good spalling resistance.

H-W MULLITE PLASTIC REFRACTORY (70% alumina) in relation to serviceability of annular brick rings and the monolithic center section, closely corresponds to the superduty fireclay brick brands of ALAMO (Mo.), H-W SUPER SAVAGE (Md.), DEAN (Pa.), BOONE (Ky.), H-W KALA (Ala.) and ZENITH (Cal.) and ANCHOR DASH 60% alumina brick.

CORALITE PLASTIC REFRACTORY (80% alumina) generally is used with greatest benefit for high temperature operations with ALUSITE brick of 70% alumina content and others containing higher percentages of alumina, in furnaces producing high temperature alloys.

Roofs of smaller furnaces for some conditions are built entirely with these plastic refractories with considerable improvement in service.

Comparative data based on experiences at many different plants involving considerable tonnages of these high-alumina plastic refractories clearly illustrate their superiority for this application. Write for further information.

HW60-32

**HARBISON-WALKER REFRACTORIES CO.**

**And Subsidiaries General Offices: Pittsburgh 22, Pa.**

***World's Most Complete Refractories Service***

# A HISTORIC TELEPHONE EXPERIMENT BEGINS IN AN ILLINOIS TOWN

**New technology brings the dream of an electronic central office to reality . . . foreshadows new kinds of telephone service.**

Today, the science of communications reaches dramatically into space, bouncing messages off satellites. But an equally exciting frontier lies closer to home. Bell Telephone Laboratories engineers have created a revolutionary new central office. At Morris, Illinois, an experimental model of it has been linked to the Bell System communications network and is being tried out in actual service with a small group of customers.

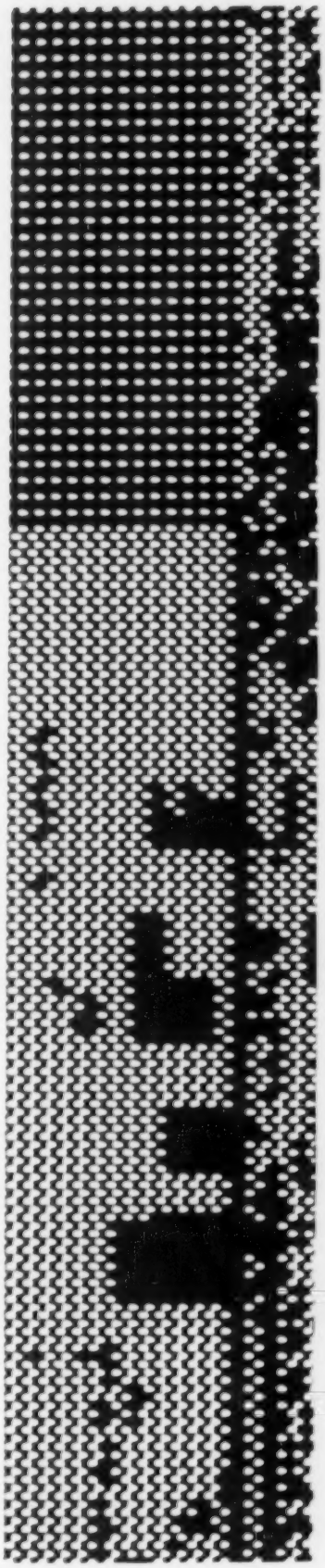
This is a special electronic central office which does not depend on mechanical relays or electromagnets. A photographic plate is its permanent memory. Its "scratch pad," or temporary memory, is a barrier grid storage tube. Gas-filled tubes make all connections. Transistor circuits provide the logic.

The new central office is versatile, fast and compact. Because it can store and use enormous amounts of information, it makes possible new kinds of services that will be explored in Morris. For example, some day it may be feasible for you to ring other extensions in your home . . . to dial people you frequently call merely by dialing two digits . . . to have your calls transferred to a friend's house where you are spending the evening . . . to have other numbers called in sequence when a particular phone is busy.

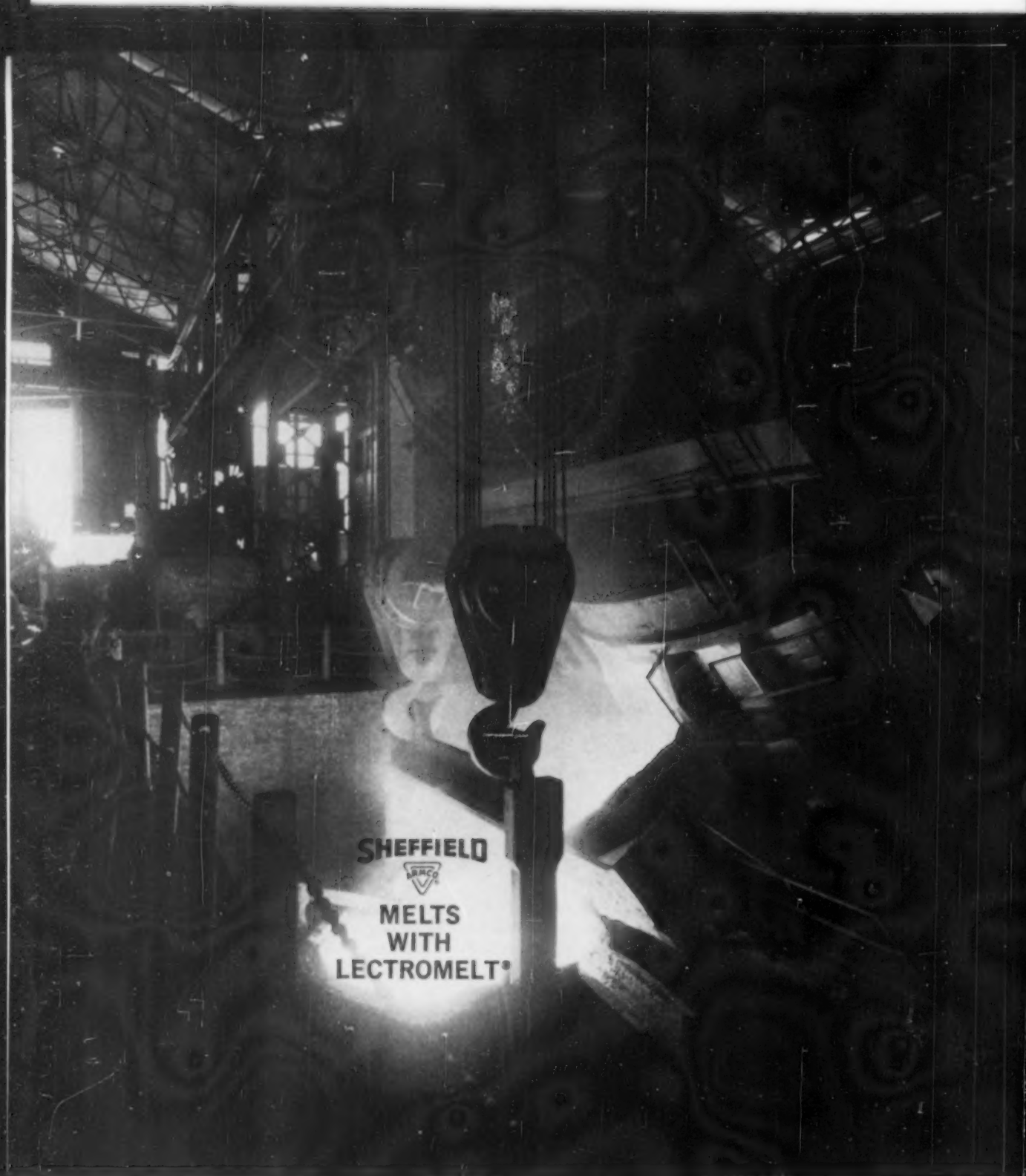
The idea behind the new central office was understood 20 years ago, but first Bell Laboratories engineers had to create new technology and devices to bring it into being. A Bell Laboratories invention, the transistor, is indispensable to its economy and reliability.

This new experiment in switching technology is another example of how Bell Telephone Laboratories works to improve your Bell communications services.

**BELL TELEPHONE LABORATORIES**
World center of communications research and development



Part of a memory plate of the new electronic central office is shown at right (enlarged 8 times). Spots are coded instructions which guide the system in handling calls and keeping itself in top operating form. Over two million spots are required. Logic and memory are physically separated in the machine, so new functions can be easily added. The experiment is being conducted in co-operation with the Illinois Bell Telephone Company and the Western Electric Company.




At the Houston works, Sheffield Division, Armco Steel Corporation, two 20-foot Lectromelt furnaces contribute high availability, accurate control and fast turn-around to volume production of high quality steels. For recommendations on furnace equipment for melting or smelting, get in touch with Lectromelt, world's largest manufacturer of electric furnaces exclusively. Lectromelt Furnace Division, McGraw-Edison Company, 326 32nd Street, Pittsburgh 30, Pennsylvania.

**WHEN YOU MELT... Lectromelt** McGRAW EDISON

# FIVE-DEEP

## Unmatched facilities nearby

help you profit with UCM's "FIVE-DEEP" Ferroalloys

❶ **Unmatched Facilities** for production and fast delivery of Union Carbide Metals' FIVE-DEEP alloys insure uninterrupted production at your metal-producing plant!

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❸ **Technology**—many million dollars worth a year—helps you produce better, more profitable metals. UCM's 600-man research and development center is the birthplace of hundreds of new alloys.

❹ **Global Ore Sources** assure you uninterrupted supplies of ferroalloys. UCM's close association with world-wide mines provides dependable raw material sources.

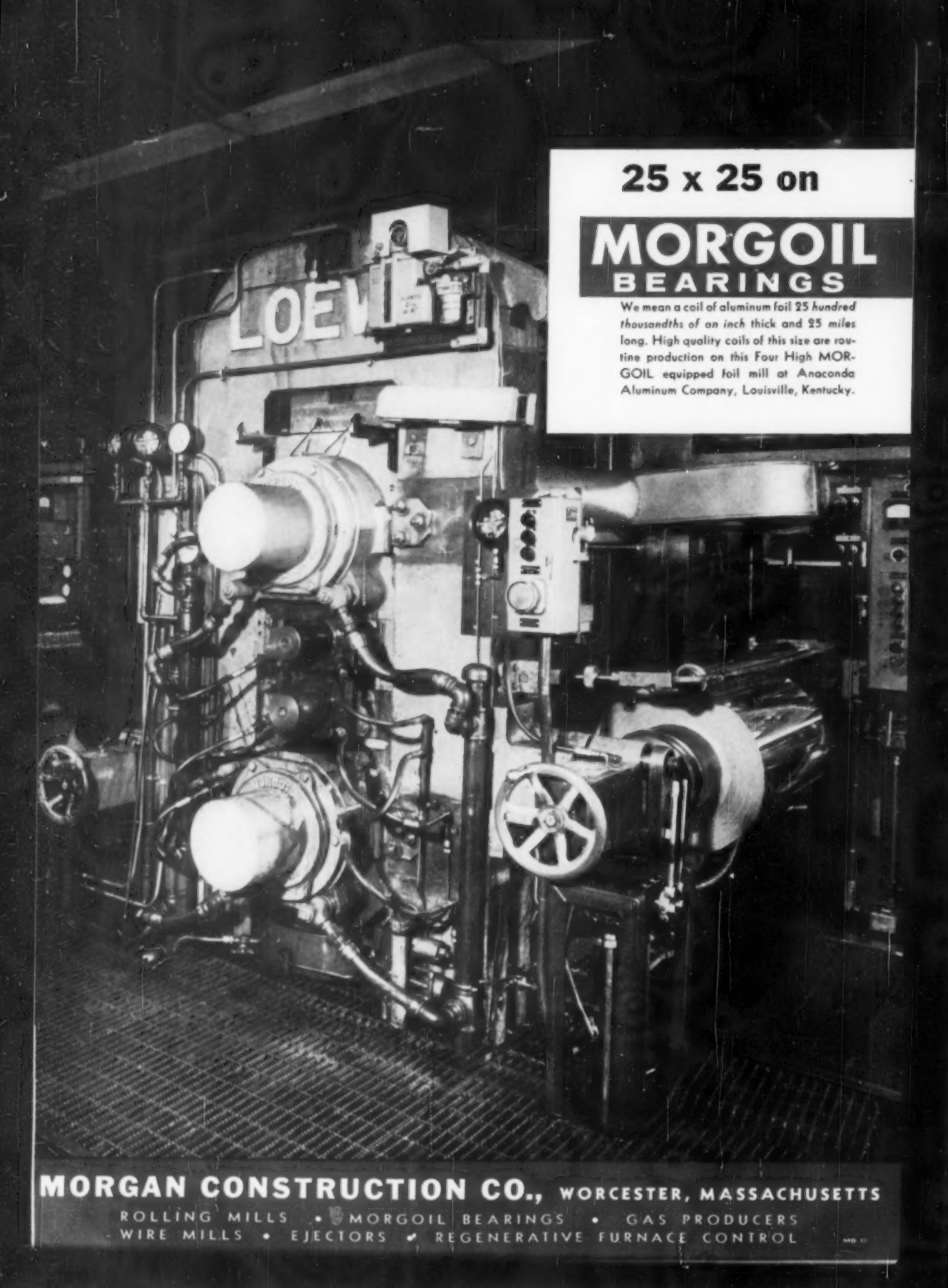
❺ **Customer Service** brings you our integrated experience in the application of ferroalloys to various melting practices. Engineers from 9 UCM field offices travel a million miles a year to provide on-the-scene assistance.

For better metals, production economies, bigger profits, insist on UCM's FIVE-DEEP alloys. Union Carbide Metals Company, Division of Union Carbide Corporation, 270 Park Avenue, New York 17, N. Y., producer of "Electromet" brand metallurgical products.

"Union Carbide" and "Electromet" are registered trade marks of Union Carbide Corporation.

UNION CARBIDE METALS

Only **ELECTROMET** ferroalloys from **UCM** are so deep in extra values to help you.


25 x 25 on
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BEARINGS
We mean a coil of aluminum foil 25 *hundred thousandths of an inch* thick and 25 *miles* long. High quality coils of this size are routine production on this Four High MORGOIL equipped foil mill at Anaconda Aluminum Company, Louisville, Kentucky.
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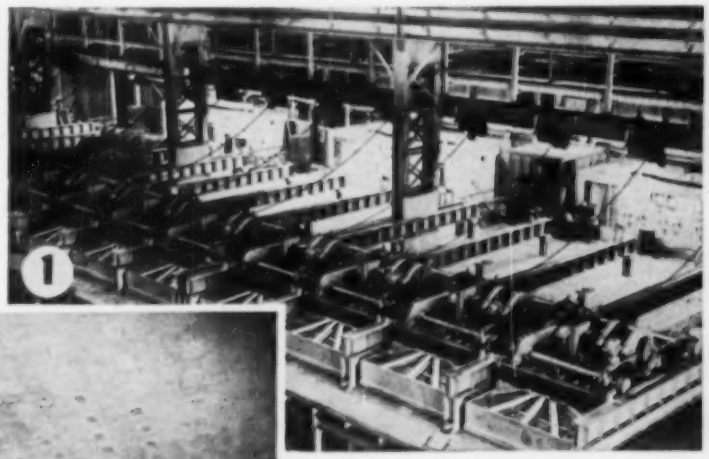
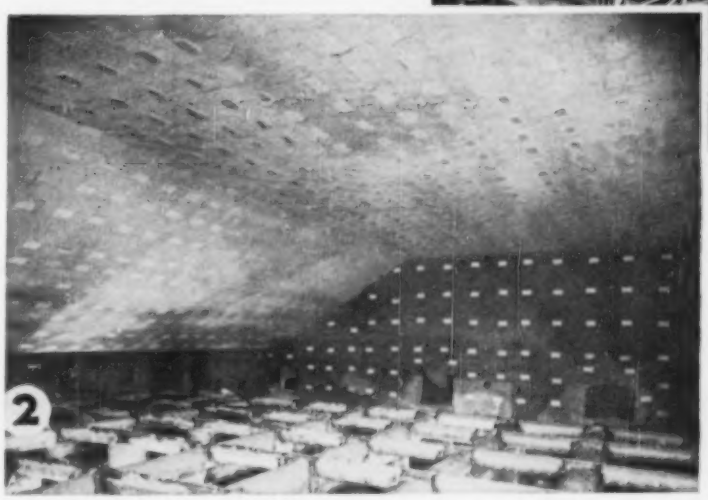
# "ACME STEEL"

## *Expands . . .*




## *– and Selects*

# Ramtite®

**1.** In an expansion program, Acme Steel Company of Riverdale, Ill. (Chicago) selected RAMTITE No. 25 for their thirteen new soaking pit covers.

For a number of years, this mill has used RAMTITE in reheat furnaces. So their experience guided them to use what could be expected to give the utmost satisfaction—SPECIAL SUPER RAMTITE No. 25.

**2.** "Acme Steel's" latest development is a triple-fired slab heating furnace, RAMTITE No. 25 was installed in its sidewalls, burner walls and roof.

RAMTITE, plastic monolithic refractory is indeed having an important part in the expansion of the Acme Steel Company.

This again proves that: "THE BEST SIGN OF SATISFACTION IS A REPEAT ORDER — WHICH IS THE BEST ENDORSEMENT."

**The versatility of the various RAMTITE products can readily solve your refractory problems. Our Sales Representative in your locality or area can be most helpful if you ask him to call. Or learn more about RAMTITE by sending the coupon below.**

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☐ We are interested in Ramtite. Please furnish information.
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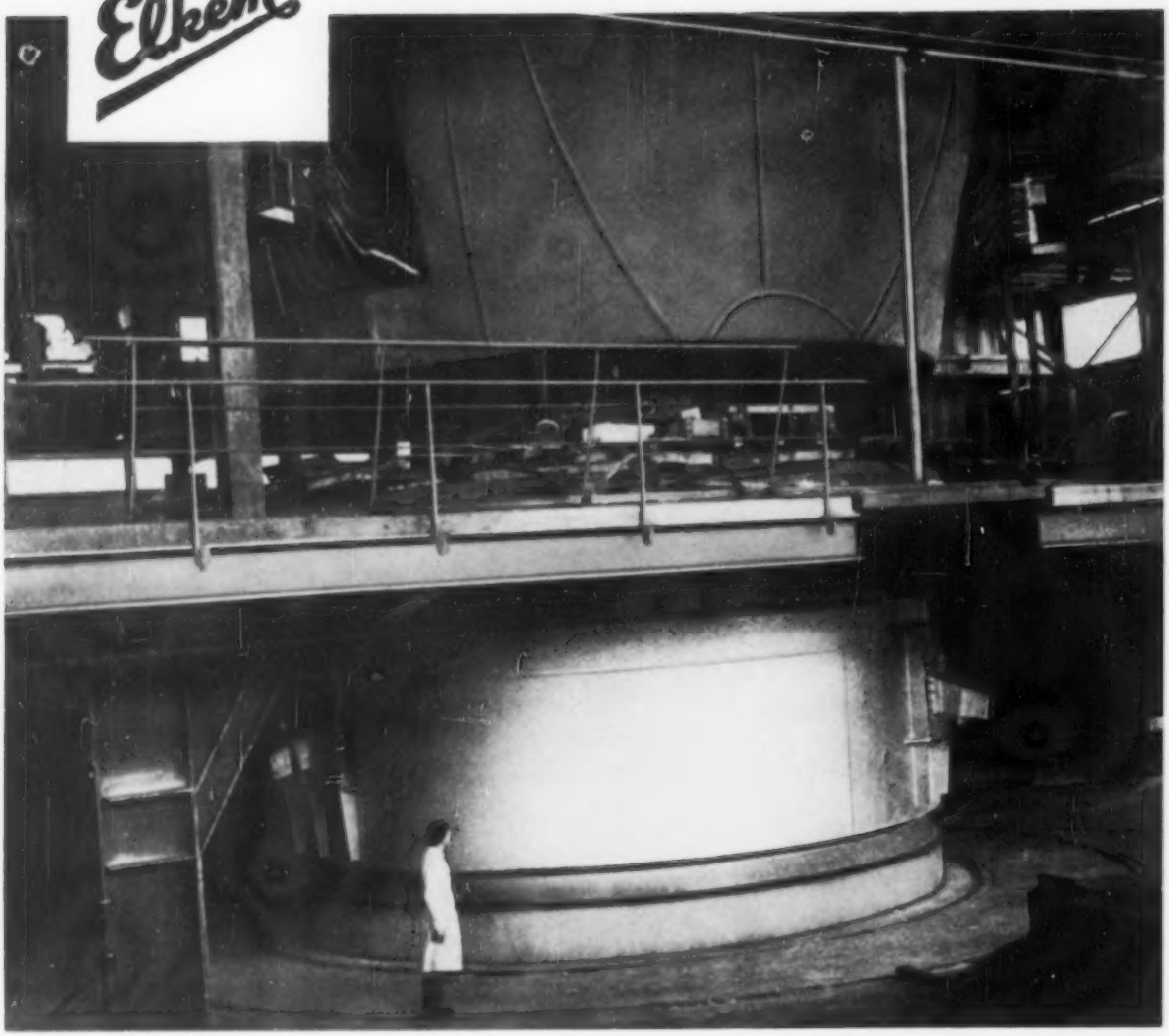

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Third Mechanical Working Conference

# BAR AND ALLIED PRODUCTS

**Wednesday, January 18, 1961 • Penn-Sheraton Hotel • Pittsburgh, Pennsylvania**

Sponsored by the Mechanical Working Committee, Iron and Steel Division, The Metallurgical Society, and Pittsburgh Section, The American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc.

## TUESDAY, JANUARY 17, 1961

### Registration

6:00-9:00 pm — Fort Duquesne Room

## JANUARY 18, 1961 WEDNESDAY MORNING

### Surface Preparation and Rolling of Primary Products

9:15 am-12:00 m — Ballroom

**Chairmen:**
R. S. Gentz, Assistant General Manager, Shape Products, Inland Steel Co., Indiana Harbor, Ind.
J. G. Parr, Professor of Metallurgy, University of Alberta, Edmonton, Alberta, Canada.

**Control of Bar Mill Quality:**
V. E. Elliott, General Supervisor—Development, and J. V. Florchak, Assistant Chief Metallurgist, U. S. Steel Corp., Gary, Ind.

**Timken's Approach to Bloom and Billet Conditioning:**
A. B. Glossbrenner, Superintendent, Conditioning, Steel and Tube Division, Timken Roller Bearing Co., Canton, Ohio.

**Billet and Bar Quality as Affected by Double Conversion and Direct Rolling Practices at The Steel Company of Canada, Ltd.:**
T. G. Bradbury, Works Metallurgist, The Steel Company of Canada, Ltd, Hamilton, Ontario, Canada.

**Effect of Composition in Causing Surface Breaks During Blooming:**
J. V. Russell, Assistant Chief Metallurgist, and R. Gaydos, Supervisor, Research and Investigation Laboratory, Republic Steel Corp., Chicago, Ill.

### Luncheon

Time: 12:00 Noon
Place: Urban Room
Price: Included With Registration Fee
Speaker: Robert B. Pease, Executive Director of The Pittsburgh Redevelopment Authority
Subject: *Pittsburgh Renaissance*

## JANUARY 18, 1961 WEDNESDAY AFTERNOON

2:00 to 5:00 pm — Ballroom

### New Developments in Processing and Testing

**Chairmen:**
M. D. Stone, Manager, Research and Development, United Engineering Co., Pittsburgh, Pa.
J. K. Seyler, Superintendent, Cold Finished Bar Division, Jones & Laughlin Steel Corp., Pittsburgh, Pa.

**New Concepts in the Production of Bar Products:**
(To Be Announced)

**Extrusion of Steel:**
D. A. Edgecombe, Superintendent, Extrusion, Babcock & Wilcox Co., Beaver Falls, Pa.

**Ultrasonic Inspection for Internal Soundness of Semi-Finished Products:**
R. N. Edmondson, Supervisor, Inspection Division, Inland Steel Co., Indiana Harbor, Ind.

**Use of Magnetic Particle Testing for Surface Defects on Bars and Allied Products:**
A. Debb, Metallurgist, Youngstown Sheet and Tube Co.

### Social Hour

5:00 to 6:00 pm — Fort Duquesne Room

### General Information

**Registration:**
Registration fee including the cost of lunch and a copy of proceedings—$13.00 for members of AIME, $15.00 for non-members.
Advance registration may be made by sending a check to Dr. T. E. Dancy, Jones & Laughlin Steel Corp., Graham Research Laboratory, 900 Agnew Road, Pittsburgh 30, Pa.

**Penn-Sheraton Hotel:**
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# "BALANCED" LININGS FOR ELECTRIC FURNACES

*Outstanding improvements in quality and application of all types of Electric Furnace Refractories have been made in recent years by Grefco's continuing field and laboratory research program on Electric Furnace Refractories. Photographic studies were made of the method of lining wear after virtually every heat of complete campaigns in numerous furnaces of various sizes and making several different types of steel. As a result of these studies, a* Special *electric furnace brick or a monolithic product has been developed for each section of the furnace—each product having been designed to give best possible service in its own particular section of the lining. The net result is "BALANCED" linings, in which every section is built with the* Special *electric furnace refractory that will give longest service in its section—regardless of the first cost of the refractory. The furnace is then pushed for production and the economics of the "BALANCED" lining is judged by the severity of service, the number of heats, the uniformity of wear, and the cost of refractories per ton of steel.*

## BOTTOMS

***Original Construction:*** Best bottoms and banks of all designs —inverted dome, stadium or herringbone—comprise largely PERATEX, dense 92+% MgO burned magnesite brick—laid with ⅛" thick joints of PERATEX BONDING MORTAR and covered with 6"-18" of dense, 92+% MgO MAGNEHARTH-15 ramming mix. These highly basic refractories give maximum resistance to extremely basic slags and, because of their unusually high thermal conductivity, they also give coolest bottoms and least maintenance (by elimination of soft bottoms and banks). For bottoms 18" thick or under, 3" of fireclay brick below the magnesite brick keeps outer shell temperatures below 500° F. For slightly lower first cost, many operators are getting excellent bottom service from GRCO-M, a dense burned magnesite brick, whose chief difference from PERATEX is its price, and somewhat lower MgO content. Since no bottom is any better than its maintenance, GRCO-M brick gives excellent service even in furnaces where conditions are severe—provided the brick are kept covered with proper thickness of MAGNEHARTH-15 or 80+% MgO MAGNEHARTH ramming mix. Some operators of large furnaces producing stainless steel, use cool inverted-dome bottoms comprising 18" of MAGNEHARTH above 13½" of PERATEX type brick. Other operators making stainless prefer "chromite" bottoms of GRCO-C, dense, burned brick made of refractory grade chrome ore.

***Bottom Maintenance:*** Slag line and banks are normally fettled with double-burned dolomite after every heat, and many operators fill holes in bottoms and banks by shoveling in MAGNEHARTH of a stiff-concrete consistency. For best results, some operators fill deep bottom holes with water; then pour loose, dry MAGNEHARTH into the boiling water until the hole is full. The violent, boiling action of the water keeps the MAGNEHARTH particles thoroughly mixed, as it settles into a dense, non-segregated, air-free monolithic mass.

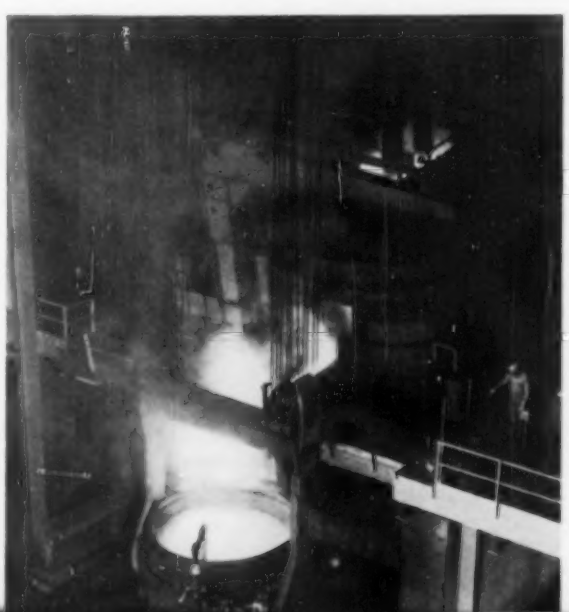
Shallow holes are best repaired by pouring them full of very thin "soupy" MAGNEHARTH, letting it boil dry and repeating until the hole is full. In both methods, the high MgO patch is topped with double-burned dolomite, giving a dense, air-free, hard patch containing almost twice as much MgO as can be obtained with the usual damp, air-filled MAGNEHARTH patches (which contain about 50% air).

## WALLS

***Original Construction:*** For lowest cost per ton of steel in lower walls, either PERATEX or GRCO-M should be used to about 6" above the slag line. In furnaces where *undercutting* is *not severe*, the best brick for the steel-plated section of walls is STEELKLAD-40 or STEELKLAD-40-EE (two internal plates). These chrome-magnesite brick have good resistance to the slag corrosion and metal erosion encountered in the lower one-third of the steel-plated section. The low thermal expansion of these brick minimizes thermal spalling and the internal plates reduce the spalling still further (since spalling is directly proportional to the area of the brick between steel plates).

Where *undercutting* in the lower one-third of the steel-plated section of wall is *moderately severe*, and thermal spalling in the upper two-thirds of this section is about equally severe, STEELKLAD-AA or STEELKLAD-AA-EE (two internal plates) magnesite-chrome brick, usually give *best balance* between the chemical attack in the slag line and "splash" areas, and the physical attack (thermal shock and impact) in the top part of the wall.

Where *undercutting* in the lower one-third of the steel-plated section of wall is *extremely severe*, dense, high MgO STEELKLAD-PB (steel plated PERATEX) gives best resistance to chemical attack and metal erosion. The high thermal expansion of STEELKLAD-PB makes it desirable to use brick of 4½ x 3" cross section in most cases—especially if service is intermittent. Where thermal spalling of STEELKLAD-PB is excessive, or where high MgO brick of slightly lower first cost are desired, STEELKLAD-M or STEELKLAD-M-EE, chemically bonded magnesite brick, give excellent service. These brick are used to good advantage in many plants, either as full walls or as the lower one-third of "two tone" walls. The most economical brick for the upper two-thirds of "two tone" walls is STEELKLAD-40 or STEELKLAD-40-EE. For very hot furnaces (where external and internal plates sometimes melt out excessively) STEELKLAD-40, STEELKLAD-AA or STEELKLAD-M with "H" plates (top and bottom plates, one internal and no edge plates) give best results, either in "two tone" construction, or in the entire steel-plated section of the wall, as needed.



Tapping a 100 ton electric furnace lined with GREFCO's special electric furnace refractories. Photo courtesy Lukens Steel Company.

*paid advertisement

***Wall Maintenance:*** Even with "zoned" linings of two or more kinds of brick in walls, it is often impossible to locate each type of brick exactly in the section of greatest wear. Thus, near the end of a campaign, it is usually economical to "gun" thin sections of the lining after every heat, in order to get maximum wear from all parts of the lining. For most furnaces using dry guns, MAGNEPATCH C-2 gun mix (78+% MgO) lasts longer and is more economical than any lower cost, lower MgO material. For wet gun application, MAGNEPATCH C-4 gives best results and MAGNEPATCH F-4 is best for application by shovel. All gunning should be done with the roof over the furnace to minimize spalling of roof and wall brick.

## ROOFS

***Silica Brick Roofs:*** For *continuous* service, in furnaces which are not exceptionally hot, it is often difficult to beat silica brick on cost per ton of steel. In some plants, roof life has been doubled by using silica skews of smallest possible cross section and silica brick of standard sizes laid with dipped joints of SILBRIK-BOND, super-duty silica mortar. The mortar reduces spalling by eliminating penetration of heat into the joints. Provision for thermal expansion of 3/32" per foot in both directions is made by proper spacing of 1/16" hard cardboard (chipboard) in the joints.

For plants which prefer block silica roofs, such as the GRIFFIN type, GREFCO silica brick have established many records for superior performance in all sections of the country. Silica brick, in either standard sizes or special shapes, can be delivered at low cost to any electric furnace plant from one of our strategically located silica brick plants. Some of the more highly regarded brands of silica brick for electric furnace use are STANDARD, GREFCO, VULCAN, PIONEER, EAGLE and VULTEX.

***Super-Duty and Zoned Roofs:*** Many plants use complete roofs of super-duty fireclay brick, available in various sections of the country as the special, spall-resistant electric furnace roof brick—HIAC-G, HIAC-K-NS (non-spall) and HIAC-S. Other plants balance the wear on roofs by using one of these super-duty fireclay brick in the major portion of the roof, with ARCO-70-NS (70% alumina—non-spall) around the electrodes, or in the hot spots, or both. In other plants, electrode ring brick are ARCO-80-NS (80% alumina) with BRIKRAM-80 Code 406 (81+% alumina ramming mix—Code 405 for non-freezing) around them, and ARCO-60-NS (60% alumina) brick outside the electrode circle. All brick are laid with dipped joints of either SILLIMANITE 340, or ARCO-BOND (63+% alumina) heat-setting mortars.

In all roofs, the idea is to get all sections to wear out at the same time. In most plants, the center section wears out first, but some plants which have higher grade refractories in the center (or smoke holes which take away the flame and basic fumes from around the electrodes) now have most trouble near the skews.

***High Alumina Roofs:*** Roofs of this type are rapidly coming into favor for electric furnaces of all sizes, with all types of operation—continuous or intermittent—and with all types of steel. The most popular roof of this type comprises special, spall-resistant ARCO-70-NS—laid with dipped joints of SILLIMANITE 340 or ARCO-BOND mortar—with BRIKRAM-80 ramming mix around the electrodes to eliminate cutting. These roofs are replacing both silica and super-duty fireclay roofs, but in some plants a close competitor on cost per ton of steel is ARCO-60-NS (60% alumina) brick and BRIKRAM-70 (70% alumina) plastic.

In roofs where this combination is better than necessary, ARCO-50-NS (50% alumina) and BRIKRAM-60 (60% alumina) plastic are used. For still less severe service—usually with super-duty fireclay or silica brick—SUPER BRIKRAM-G (super-duty fireclay plastic) or BRIK-CAST 3200 (mullite base castable) are used around the electrodes to eliminate cutting.

In any case, cutting has been eliminated in most plants and the service of center sections has been doubled, in some plants, by the use of the proper plastic, ramming mix or castable within the electrode circle wherever a full sized brick will not fit. Roof building time has often been cut to one-third of that needed to "cut in" a center—thus saving a great deal of time and hundreds of dollars worth of labor per roof on the larger furnaces.

A few plants use complete roofs of either SILLIMANITE (mullite), ARCO-80-NS (80% alumina), ARCO-85-NS or ALTEX-85 (both 85% alumina) brick or high alumina ramming mixes—usually in small furnaces with intermittent operation or making special steel. Several plants have standardized on complete roofs of BRIKRAM-80 for furnaces up to 6′ in diameter. It is important that the BRIKRAM-80 be rammed at an angle of 45° to the hot face to eliminate "slabbing" due to laminations.

***Basic Roofs:*** The rapidly increasing use of all-basic roofs in open hearth steel furnaces has caused much greater interest in basic brick for electric furnace roofs. Basic brick are fundamentally sound because electric furnace fumes are strongly basic. Several plants have used basic skews, or skews plus outer rings—with or without basic panels in the hot spots—for the past 10 years or more. Several plants in Europe have been using basic roofs on small electric furnaces for many years. In this country, basic roofs have recently replaced 90% alumina brick as standard practice on some small foundry electric furnaces.

To date, the best basic roofs have been built with spall-resistant STEELKLAD-40-EE of 4½ x 3" cross section, laid in KROMESET air-setting chrome mortar. On the larger furnaces, the rings must be keyed very tightly to avoid slippage and eventual sagging when the furnace is tilted. In some of the largest furnaces, basic brick are needed only in the hot spots—but in others they are needed all the way around, several feet out from the roof ring (where 70% alumina brick fail rapidly due to slag corrosion).

At present, it appears that the center section problem (where steel-plated brick can cause arcing) may be solved by BRIKRAM-90 (90% alumina) ramming mix around the electrodes, and RITEX-40 (unburned chrome-magnesite brick) elsewhere. Several plants in this country are now trying 9" basic roofs on furnaces of various sizes, including those 20′, 22′ and 24′ in diameter. It is believed that, in due time, 9" basic roofs of STEELKLAD-40-EE, STEELKLAD-AA-EE or STEELKLAD-M-EE will be standard practice for electric furnaces where service is so severe that even 70% alumina brick give very short life. The cost and weight of a 9" roof of STEELKLAD-40-EE is about the same as that of a 13½" roof of 70% alumina brick, and cost per ton of steel should be less with the basic brick in many cases. In some of the larger furnaces it may be necessary to have some, or all, of the brick held up and held down by a reusable steel corset to avoid sagging and buckling when the roof wears thin in areas of greatest wear.

***Refractory Doughnuts:*** More and more plants are substituting homemade, prefabricated refractory doughnuts for the troublesome, hazardous and expensive electrode water coolers. Some plants use steel reinforced HIGH STRENGTH BRIK-CAST, SUPER BRIKRAM or HIAC arch brick when service is easy, and PCO (Plastic Chrome Ore), HIGH STRENGTH BASICRETE, MAGNEPATCH and RITEX-40 where service is tough. CARBEX type (silicon carbide) brick and high duty fireclay brick have also been used successfully between the electrodes and the water chamber of composite water-brick type electrode coolers.

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If you are not perfectly satisfied with the refractories used in your electric furnace, GREFCO will be pleased to have a *Specialist* on Electric Furnace Refractories study your problems and recommend refractories which will give you a *BALANCED* lining. You are also invited to send for your free copy of "Electric Furnace Refractories"—a discussion of modern refractories practice in Basic Electric Steel Furnaces.

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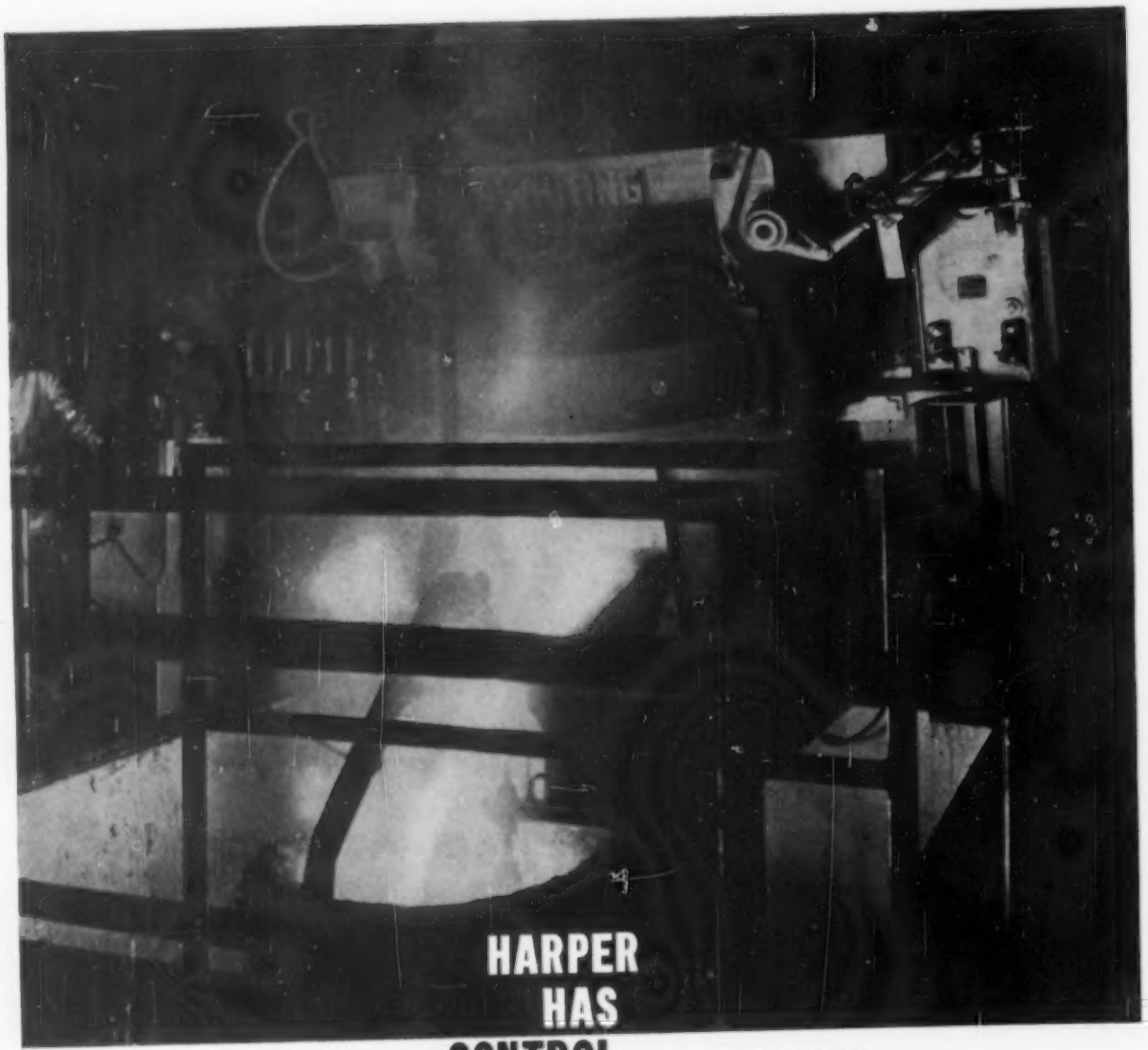

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## Personals

*(Continued from page 888)*

honors long and distinguished service of a teacher of metallurgical engineering or related subjects.

**George B. McMeans** is now vice president of Kaiser Industries Corp., and Henry J. Kaiser Co. He was formerly vice president of Kaiser Steel Corp.

**Harold W. Paxton,** associate professor of metallurgical engineering at Carnegie Institute of Technology, has received the American Society for Metals' $2000 Bradley Stoughton Award for outstanding young teachers of metallurgy.

**Charles W. Phillips** has been named manager of the research services department of Ford Motor Co.'s scientific laboratory. He was formerly supervisor of the process and mechanical metallurgy section.

**George A. Roberts** has been reelected president of the Metal Powder Industries Federation.

**R. William Rosenquist** has been promoted to manager of metal sales for the eastern div. of New Jersey Zinc Co. **Charles H. Prince** is now manager of technical service of the metal div.

*(Continued on page 970)*


**SENIOR SCIENTIST**

Interesting and challenging position available in Materials Department for a capable scientist in physical metallurgy who will be responsible for the technical progress of research projects.

Position requires a Ph.D. in physical metallurgy with major graduate study and research in the physics of metal and materials science.

Recent graduate to eight years post doctorate in experimental research with emphasis on basic metallurgical phenomena with genuine interests and knowledge in one or more of the following areas: refractory metals, deformation and fracture processes, alloy development and constitution, crystals growth and purification processes, whiskers and thin films, high temperature properties and reactions, and phase transformations.

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Five years experience in Theoretical Polymer Science, mechanisms of viscoelastic polymers, reinforced plastics and adhesives and physico-chemical studies of polymer materials.

We would also welcome resumes from qualified engineers and scientists in the fields of metals, plastics and ceramics.

Interested applicants should forward complete resume to Mr. J. V. Starbuck, Box JM, Salaried Personnel, **AERONUTRONIC,** Ford Road, Newport Beach, California.

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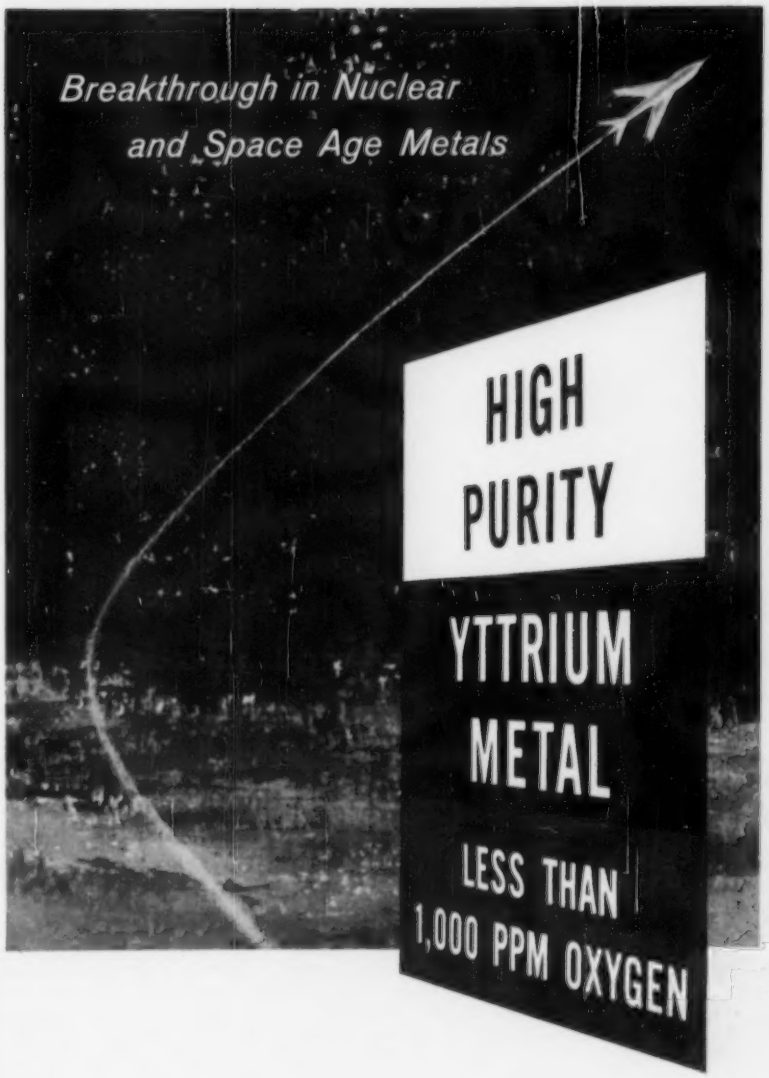


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# education

### Olin Laboratory

The Olin Foundation, Inc., has made a grant of $1,637,000 to Case Institute of Technology, Cleveland, Ohio. The funds will be used to build and equip a new Olin Laboratory for Materials Sciences. The laboratory will develop new metals for use in such projects as space ships, high-speed missiles, and nuclear power plants. The building will be eight stories high and construction is scheduled to begin next year. The laboratory will include facilities for structural testing, soil physics, bionics, chemical analysis, sanitary engineering, and instrumentation.

The Olin Foundation was founded in 1938 with gifts from the late Franklin W. Olin. It has contributed heavily to American education, largely in the form of grants for buildings.

### Electron microscopy

A two-week course on Electron Microscopy in Metallurgy, designed to acquaint scientists with the uses of electron microscopes for studies in the solid state, will be offered by the Department of Mineral Technology at the University of California, Berkeley, June 19-30, 1961. The course is limited to 50 participants.

The course will cover preparation of specimens, with emphasis on thin sections for direct transmission, electron diffraction, theory of contrast in electron microscopes, and the use of the R.C.A.E.M., Hitachi H.U. 10, and Siemens Elmiskop microscopes. Laboratory work and informal discussions are planned to supplement lectures.

Preliminary inquiries can be directed to Gareth Thomas, Department of Mineral Technology, University of California, Berkeley. For further information on application and enrollment, contact University of California Extension, 2441 Bancroft Way, Berkeley 4, Calif.

### Tau Beta Pi

Representatives of 103 colleges and universities from 39 states attended the 75th anniversary convention of Tau Beta Pi, national engineering honor fraternity, October 12-14 at Lehigh University, Bethlehem, Pa. A special feature of the convention was the unveiling of a monument on the campus to commemorate the founding of the society in 1885 by the late Prof. Edward H. Williams, Jr., at Lehigh.

### NSF fellowships

Applications are being accepted for National Science Foundation Graduate Fellowship awards for advanced study in the sciences. Fellowships will be awarded in the mathematical, physical, biological, and engineering sciences, and others. Also included are interdisciplinary fields.

To be eligible for Graduate Fellowships, applicants must be citizens or nationals of the US, and have demonstrated ability and special aptitude for advanced training in the sciences. Fellows will be selected on the basis of ability attested by letters of recommendation, academic records, and other appropriate evidence of scientific competence. Applicants are required to take the Graduate Record Examination.

Stipends for fellowships vary with the academic status of the Fellows. Application material for the Fellowship Program may be obtained from the Fellowship Office, National Academy of Sciences-National Research Council, 2101 Constitution Ave., N.W., Washington 25, D.C. The closing date for the receipt of applications is January 6, 1961. Final selection of Fellows will be announced March 15, 1961.

### ARF fracture research

A fundamental research program to determine the basic factors that influence the fracture of non-metallic ceramic materials has been started by Armour Research Foundation under sponsorship of Wright Air Development div.'s Materials Control.

The 18-month, $460,000 study will be conducted by a team of ARF researchers in physics, ceramics, metals, and mechanics, and by scientists at universities and industrial research laboratories in the US and Europe.

Primary purpose of the research

(*Continued on page 967*)


**Research and Development Metallurgists**

Youngstown Sheet & Tube Co. has several excellent career opportunities for qualified men in its new program of expansion in research and development.

B.S. or advanced degrees are required for positions involving both technical and supervisory responsibilities. Openings in areas of process, physical and product metallurgy. Also in coating and corrosion and raw materials field.

Salaries based on experience and education. Send complete resumes to: R. A. Nittinger, Assistant Manager, Organization & Development, Youngstown Sheet & Tube Co. Youngstown, Ohio.

**MANAGER OF METALLURGICAL RESEARCH**

A manager is sought for a metallurgy research division. He should be a Ph.D. degree man with evidence of high quality work output in non-ferrous metals, ferro-alloys or powder metallurgy research. Competence in physical metallurgy is required. Job will require program planning, supervision of technical men, editing of reports. The company offers challenge and growth potential to this man. Results sought are not "quick and dirty" answers but results of long term significance. Salary commensurate with responsibility and qualifications. Reply to Director of Research Foote Mineral Company, Box 576, Berwyn, Pa.

Less than **25** parts per million aggregate impurities were found by independent laboratory test in the ultra-purity single crystals processed in MRC's electron beam floating zone apparatus.

| | *Oxygen* | *Hydrogen* | *Carbon* | *Nitrogen* |
|---|---|---|---|---|
| *Tungsten* | *2.6 ppm* | *0.4 ppm* | *none* | *7 ppm* |
| *Molybdenum* | *7 ppm* | *0.7 ppm* | *15 ppm* | *3 ppm* |
| *Tantalum* | *6 ppm* | *2.9 ppm* | *10 ppm* | *8 ppm* |

These ultra-purity single crystals in all crystallographic orientations are available in ⅛" diameter in tungsten, columbium and molybdenum, in ¼" and ⅛" diameter in tantalum, both sizes in lengths up to 8".

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# 18th Annual Electric Furnace Program

Sponsored by the Electric Furnace Committee of the Iron and Steel Division, The Metallurgical Society of The American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc.

## Morrison Hotel, Chicago — November 30-December 2, 1960

### REGISTRATION

Wednesday, Thursday, and Friday, November 30-December 2—8:30 am to 5:00 pm—1st Floor Foyer.

### TUESDAY, NOVEMBER 29

5:00 pm—Embassy Room

**Business Meeting:**
Electric Furnace Committees Annual Dinner and Business Meeting

### WEDNESDAY, NOVEMBER 30

**Authors and Chairmen Breakfast: 8:00 am—Embassy Room.** Authors and session chairmen will meet for breakfast followed by an opportunity to plan final details with regard to the schedule of papers for each session.

## Joint Technical Session

### WEDNESDAY, November 30

9:30 to 9:45 am—Grand Ballroom

### General Session

**Welcoming Remarks:**
By G. C. Olson, Chairman, Committee for the Eighteenth Annual Conference.

**Response:**
By P. R. Gouwens, Chairman, Electric Furnace Committee—Announcements and Reports.

9:45 am to 12:30 pm—Grand Ballroom

### Non-Metallic Inclusions in Steel

(Arranged by Physical Chemistry of Steelmaking Committee)

**Chairmen:**

F. C. Langenberg, Manager of Process Research, Crucible Steel Co. of America, Pittsburgh, Pa.
B. M. Shields, Chief Metallurgist, Duquesne Works, United States Steel Corp., Duquesne, Pa.

1. **Techniques for the Study of Nonmetallic Inclusions:**
Paper by W. D. Forgeng, Research Metallurgist, Union Carbide Metals Co., Niagara Falls, N. Y.

2. **Inclusions in Stainless Steel:**
Paper by D. C. McCarter, Melt Shop Metallurgist, Dunkirk Works, and S. Ramachandran, Supervising Research Metallurgist, and J. C. Fulton, Chief Research Metallurgist, Research Center, Allegheny Ludlum Steel Corp., Brackenridge, Pa.

3. **Inclusions in High-Temperature Alloys and Ferritic Steels:**
Paper by Alexander Nagy, Research Associate, and W. J. Pennington, Research Associate, Universal-Cyclops Steel Corp., Bridgeville, Pa.

4. **Quantitative Extraction of Non-Metallic Inclusions From Steel:**
*Paper by H. Walz, Research Metallurgist, and R. A. Bloom, Section Chief, Process Metallurgical Research, Timken Roller Bearing Co., Canton, Ohio.

5. **Petrographic Tools and Techniques in Examining Non-Metallic Inclusions in Steels:**
Paper by R. G. Wells, Senior Research Metallurgist, and J. M. Snook, Staff Metallurgist, Crucible Steel Co. of America, Pittsburgh, Pa.

* Preprinted Paper

## Combined Technical Session

## Ingot and Special Arc

2:00 to 5:00 pm—Grand Ballroom

### Factors in Improving Steel Quality

**Chairmen:**

H. M. Parker, Melting Superintendent, Armco Steel Corp., Butler, Pa.

G. E. Willey, General Sales Manager, Metals and Carbon Division, Union Carbide Canada Ltd., Toronto, Ontario, Canada.

1. **Reliability Factors in Steel Usage:**
   Paper by H. Thomas Hallowell, Jr., President, Standard Pressed Steel Co, Jenkintown, Pa.

**WEDNESDAY, NOVEMBER 30**

## Ferro-Alloy Quality and Standardization vs. Steel Quality

1. **The Ferro-Alloy Situation as Seen by a Ferro-Alloy Producer:**
   Comments by G. E. Willey, General Sales Manager, Metals and Carbon Division, Union Carbide Canada Ltd., Toronto, Ontario, Canada.

2. **Hydrogen in Alloy Additives:**
   Paper by E. R. Saunders, Metallurgical Engineer, Union Carbide Metals Co., Cleveland, Ohio, G. Porter, Research Chemist, and J. L. Lamont, Research Metallurgist, Union Carbide Metals Co., Niagara Falls, N. Y.

3. **Non-Metallic Inclusions in Alloy Additives:**
   Paper by E. R. Saunders, Metallurgical Engineer, Union Carbide Metals Co., Cleveland, Ohio, W. D. Forgeng, Research Metallurgist, and J. W. Farrell, Metallurgical Engineer, Union Carbide Metals Co., Niagara Falls, N. Y.

4. **The Ferro-Alloy Situation as Seen by a Steel Producer:**
   Comments by H. M. Parker, Melting Superintendent, Armco Steel Corp., Butler, Pa.

5. **Ferro-Alloy Quality Vs. Steel Quality:**
   (a) Paper by R. P. de Vries, Assistant to Manager of Quality Control, Allegheny Ludlum Steel Corp., Watervliet, N. Y.
   (b) Paper by P. B. Dennis, Chief Plant Metallurgist, Atlas Steels Ltd., Welland, Ontario, Canada.

6. **What is Being Done to Standardize Types and Grades of Ferro-Alloys?**
   Comments by S. W. Poole, Research Metallurgist, Republic Steel Corp., Brecksville, Ohio; and Chairman, ASTM A-9 Committee on Ferro-Alloys.

### ANNUAL DINNER

**Thursday, December 1**

6:30 pm—Constitution Room—Reception and Cocktail Party for dinner guests.

7:00 pm—Ballroom—Dinner

**Toastmaster:** Foster C. Brown, President, Ceco Steel Products, Cicero, Ill.

**Speaker:** Charles J. Hunter, General Superintendent, South Works, United States Steel Corp., Chicago, Ill.

**Subject:** Economic Optimism.

# Castings Technical Session

**WEDNESDAY, NOVEMBER 30**

**2:00 to 5:00 pm—Constitution Room**

## Control of Non-Metallics in Steel for Castings

**Chairmen:**

A. F. Gross, Chief Metallurgist, Ohio Steel Foundry Co., Springfield, Ohio.
S. O. Smith, General Manager, Mercer Alloy Crop., Greenville, Pa.

1. **Treatment of Steel With Magnesium to Ease the Sulphur Problem:**
   Paper by W. B. Brooks, Metallurgical Specialist, Texas Division, The Dow Chemical Co., Freeport, Texas.
   Discussion: R. F. Knight, and D. E. Parsons, Scientific Officer, Department of Mines and Technical Surveys, Ottawa, Canada.

2. **Vacuum-Degassing of 500-lb. Melts for Carbon Steel Castings:**
   *Paper by D. E. Parsons, Scientific Offices, Department of Mines and Technical Surveys, Ottawa, Canada.

3. **Pressure Pouring of Steel Castings:**
   Paper by Thomas Quinn, Jr., Manager, Carbon Steel Foundry, Lebanon Steel Foundries, Lebanon, Pa.
   Discussion: J. Woodburn, Director of Research, Griffin Wheel Co., Chicago, Ill.

4. **Desulphurizing of Steel Under Production Conditions:**
   Paper by John McBroom, President, and Thomas Johnson, Stainless Foundries and Engineering Co., Inc., Milwaukee, Wisc.
   Discussion: E. A. Loria, Metallurgical Development Manager, Climax Molybdenum Co., Div. of American Metal Climax, Inc., Pittsburgh, Pa.

* Preprinted Paper

# Ingot Technical Session

**THURSDAY, DECEMBER 1**

**9:30 am to 12:30 pm—Grand Ballroom**

## Some Developments in Steelmaking Processes

**Chairman:**

T. J. Wayne, Superintendent, Electric Furnaces, South Works, United States Steel Corp., Chicago, Ill.

1. **Vacuum Degassing for Better Forgings:**
   Film Presentation of Bethlehem Steel Co. Discussion of Film, *Effect of Vacuum Degassing on*

*Steel Quality*: A. L. Lehman, Superintendent, Electric Furnaces, Bethlehem Steel Co., Bethlehem, Pa.

2. **A Refractory Quality Control Program for Steel Plant:**
   Paper by E. C. Rudolphy, Chief Research Metallurgist, and Arthur Sontz, Supervisor, Ceramic Development, South Works, United States Steel Corp., Chicago, Ill.

3. **Oxygen as an Aid to Electric Furnace Economics:**
   Paper by A. K. Blough, Superintendent, Melt Shops, Republic Steel Corp., Canton, Ohio.

4. **Summary of Direct Reduction Processes as Applied to Electric Furnace Use:**
   Paper by G. G. Hatch, President, W. S. Atkins and Associates Ltd., Toronto, Ontario, Canada.

5. **Basic Brick Trials in Electric Furnace Roofs:**
   Paper by W. H. Schaefer, Associate Ceramic Engineer, and W. C. Kollman, Superintendent, Electric Furnaces, Crucible Steel Co. of America, Midland, Pa.

6. **Electric Furnace Bottoms and Their Maintenance:**
   *Paper by E. F. Franzen, Superintendent, Electric Furnaces, A. Finkl and Sons Co., Chicago, Ill.

* Preprinted Paper

## Castings Technical Session

THURSDAY, DECEMBER 1

9:30 am to 12:30 pm—Constitution Room

### Refining Metal in Air Induction Melting

**Chairmen:**

John McBroom, President, Stainless Foundries and Engineering Co., Inc., Milwaukee, Wisc.
S. E. Wolosin, Supertindent of Melting, Lebanon Steel Foundries, Lebanon, Pa.

1. **Manganese-Silicon Ratio in Air Induction Melting of Stainless Steel:**
   Paper by J. Fuqua, Foundry Superintendent, Cooper Alloy Corp., Hillside, N. J.

2. **Slag Compositions Used in Air Induction Melting:**
   Paper by W. W. Moore, Metallurgist, and N. H. Keyser, Metallurgist, Battelle Memorial Institute, Columbus, Ohio.


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3. **Production of Low-Gas Content Metal Using Argon Atmosphere:**
   Paper by Elwood Bowen, Melting Superintendent, Ohio Steel Foundries, Springfield, Ohio.
   Discussion: S. E. Wolosin, Superintendent of Melting, Lebanon Steel Foundries, Lebanon, Pa.

4. **Oxidation Behavior in High-Alloy Air Induction Melting and Control with Argon Blanket:**
   Paper by Thomas Watmough, Research Metallurgist, and Paul Gouwens, Supervisor, Foundry Metals Research Section, Armour Research Foundation, Chicago, Ill.

5. **Oxygen Boil in Air Induction Melting:**
   Paper by Richard Atkinson, Melting Metallurgist, Carpenter Steel Co., Portland, Ore.

6. **Desulphurization of Induction Melted Plain Carbon and Low-Alloy Steels:**
   *Paper by C. H. Lumpp, Research Metallurgist, American Steel Foundries Co., East Chicago, Ind.

7. **Reduction of C, S, and P through Oxidation in Air Induction Melting:**
   Paper by Leroy Fink, Supervising Metallurgist, Electric Steel Foundry Co., Portland, Ore.

8. **Optimum Desulphurization and Dephosphorization in Air Induction Melting:**
   Paper by John Zotos, Assistant Professor, Northeastern University, Boston, Mass.

* Preprinted Paper

## "Special Arc" Technical Session

THURSDAY, DECEMBER 1

9:30 am to 12:30 pm—Cotillion Room

### Manufacture of Carbide and Phosphorus

**Chairmen:**

F. E. Large, Director of Engineering and Research, National Carbide Co., Calvert City, Ky.
M. M. Striplin, Jr., Chemical Engineer, Tennessee Valley Authority, Wilson Dam, Ala.

1. **Considerations in the Use of Large vs. Small Carbide Producing Furnaces:**
   Paper by B. R. Gray, Production Manager, National Carbide Co., Calvert City, Ky.
   Discussion: G. J. Kiedaisch, Chief Engineer and Superintendent, Midwest Carbide Co., Keokuk, Iowa.

2. **Operation of a 43,500 KVA Carbide Furnace at Trostberg, Germany:**
   Paper by Franz Kaess, Suddeutsche Kalkstickoff Werke A. G., Trostberg, Upper Bavaria, West Germany.
   Discussion: C. B. Carlson, Manager, Smelting Furnace Sales, Lectromelt Furnace Div., McGraw-Edison Corp., Pittsburgh, Pa.

3. **Operation of an Electric Furnace in Manufacturing Phosphorus:**
   Paper by Arturo Chavez, Superintendent, Electric Reduction Co., Varennes, Quebec, Canada.

4. **Handling and Utilization of Phosphorus Furnace Slag:**
   *Paper by J. C. Barber, Chief, Plant Chemical Control Branch, and M. M. Striplin, Jr., Chemical Engineer, Tennessee Valley Authority, Wilson Dam, Ala.

* Preprinted Paper

## Ingot Technical Session

**THURSDAY, DECEMBER 1**

2:00 to 5:00 pm—Grand Ballroom

### Stainless Steel

**Chairmen:**

R. P. Hill, Electric Furnace Superintendent, Sharon Steel Corp., Sharon, Pa.
S. J. Myford, Melting Superintendent, Copperweld Steel Co., Warren, Ohio.

1. **Stainless 430:**
   (a) **Cleanliness Requirements for 430 Stainless Steel Strip:**
   Paper by S. P. Odar, Assistant Plant Metallurgist, Republic Steel Corp., Massilon, Ohio.
   (b) **Metallurgical and Operating Problems in Processing Stainless 430 Strip:**
   Paper by L. Nemethy, Manager, Process Development, and P. B. Dennis, Chief Plant Metallurgist, Atlas Steels Ltd., Welland, Ontario, Canada.
2. **Controlled Oxygen Blow in Melting of Chrome-Nickel Stainless Steels:**
   Paper by W. M. Hyams, Development Metallurgist, Crucible Steel Co. of America, Midland, Pa.
3. **Oxygen Practice on Stainless Steels at Sharon Steel Corporation:**
   Paper by R. P. Hill, Electric Furnace Superintendent, Sharon Steel Corp., Sharon, Pa.
4. **Fluid Mold Casting:**
   Paper by Thomas Evans, Superintendent, Melting, National Supply Co., Torrance, Calif.
5. **Argon Casting:**
   (a) **Argon Casting for Improving Steel Quality:**
   Paper by M. F. Hoffman, Project Engineer, P. G. Bailey, Development Engineer, Development Laboratory, Linde Company, Newark, N. J., and R. L. W. Holmes, Development Engineer, Linde Gases Division, Union Carbide Canada, Ltd., Toronto, Ontario, Canada.
   (b) **Argon Casting at Jessop Steel Company:**
   Paper by W. R. Lysoby, Air Reduction Sales Co., Murray Hill, N. J.
6. **Exothermic Hot Topping Big-End-Down Ingots for Higher Yields:**
   Paper by T. C. McConnon, Manager, Steel Division, Pittsburgh Metals Purifying Co., Inc., Mars, Pa.

## Castings Technical Session

**THURSDAY, DECEMBER 1**

2:00 to 5:00 pm—Constitution Room

### New Developments

**Chairmen:**

N. H. Keyser, Metallurgist, Battelle Memorial Institute, Columbus, Ohio
A. J. Kiesler, Metallurgical Engineer, Research Laboratory, General Electric Co., Schenectady, N. Y.

1. **Auxiliary Meltdown Torch in Electric Furnaces:**
   Paper by V. J. Howard, Melting Foreman, Oklahoma Steel Castings Co., Tulsa, Okla.
2. **New Developments in the Analysis of Carbon and Sulphur:**
   Paper by Elliott DuBois, Chief Engineer, Spectro Chemical Division, Baird Atomics, Cambridge, Mass.
3. **Complete Analysis of Basic Open Hearth Bath Samples Using the Quantovac:**
   Paper by John Kelly, Steel Co. of Canada Ltd., Hamilton, Ontario, Canada.
4. **Iron Ore to Steel in the Electric Furnace by the Madrigal Process:**
   Paper by C. B. Reynolds, International Ore Processing Co., North Hollywood, Calif.
5. **Future Possibilities in Melting:**
   (a) Paper by J. F. Elliott, Associate Professor of Metallurgy, Massachusetts Institute of Technology, Cambridge, Mass.
   (b) Paper by W. W. Moore, Metallurgist, John Varga, Jr., Metallurgist and N. H. Keyser, Metallurgist, Battelle Memorial Institute, Columbus, Ohio.
   (c) Discussion: P. R. Gouwens, Supervisor, Foundry Section-Metals, Armour Research Foundation, Chicago, Ill.

## "Special Arc" Technical Session

**THURSDAY, DECEMBER 1**

2:00 to 5:00 pm—Cotillion Room

### Manufacture of Ferro-Alloys

**Chairmen:**

A. C. Haskell, Jr. Chief, Process Metallurgy Division, Research Department, Titanium Alloy Manufacturing Div., National Lead Co., Niagara Falls, N. Y.
C. C. Whiting, Jr., Chrome Product Manager, Union Carbide Metals Co., Niagara Falls, N. Y.

1. **Single-Stage Manufacture of Low-Carbon Ferrochromium Silicon:**
   Paper by W. R. Meredith, Assistant General Superintendent, Interlake Iron Corp., Beverly, Ohio.

Electric Furnace Steel Suppliers who have parlors for entertaining have been requested and are anxious to cooperate in closing their rooms during technical sessions and the dinner on Thursday. Please help them cooperate by voluntarily leaving or avoiding their rooms at these times.

Discussion: (a) M. J. Geigel, Chief, Metallurgist, Chromium Mining and Smelting Corp., Chicago, Ill.
(b) C. G. Adler, Plant Manager, Graham Plant, Vanadium Corp. of America, New Haven, W. Va.

2. **Manufacture of Simplex Ferrochrome by the Vacuum Process:**
Paper by C. G. Chadwick, Group Manager, Vacuum Technology, Union Carbide Metals Co., Niagara Falls, N. Y.

3. **Manufacturing 75 Per Cent Ferrosilicon in a Large Submerged-Arc Furnace:**
*Paper by W. H. Wise, Assistant Superintendent, Pittsburgh Metallurgical Co., Inc., Calvert City, Ky.
Discussion: A. J. Primosic, Manager of Operations, Keokuk Electro Metals Co., Div. of Vanadium Corp. of America, Keokuk, Iowa.

4. **Casting Procedures for Ferro-Alloys:**
*Paper by H. W. Rathmann, Director of Process Research, Vanadium Corp. of America, Cambridge, Ohio
Discussion: H. R. Tuten, Assistant Furnace Superintendent, Interlake Iron Co., Beverly, Ohio.

* Preprinted Paper


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## "Special Arc" Technical Session

**THURSDAY, DECEMBER 1**

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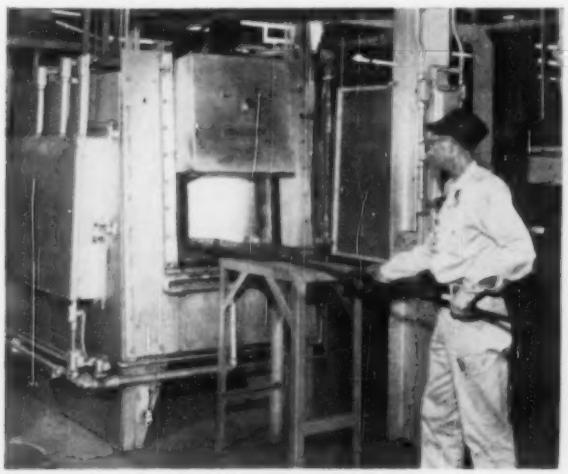
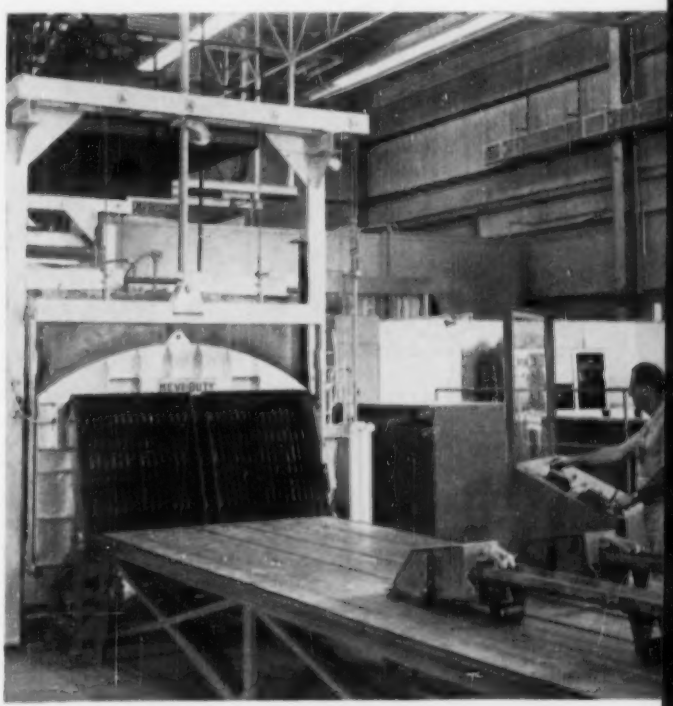


This box furnace was designed to handle copper brazing and heat treating in an endothermic atmosphere. Its water-jacketed cooling chamber and oil quench tank are atmosphere-protected. There are door curtain burners at each end. North American reports it is getting exceptionally clean work from this furnace due to the enclosed quench. ***For complete information ask for Bulletin No. 153.***



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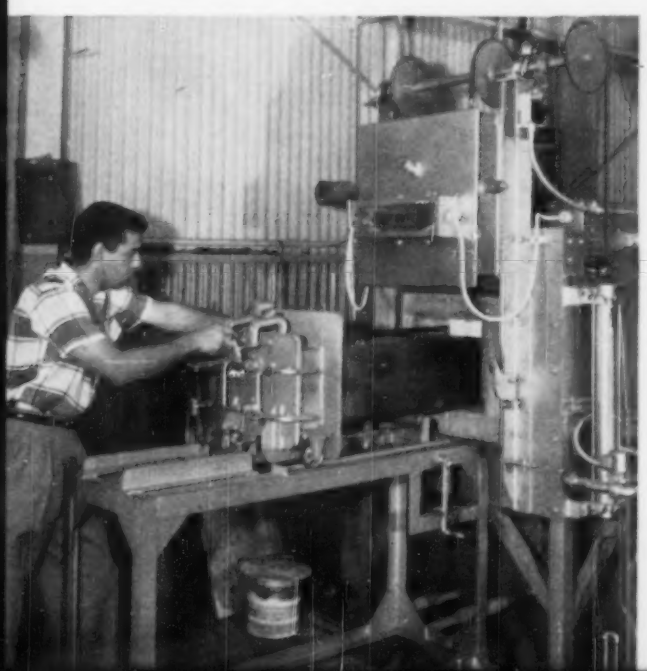

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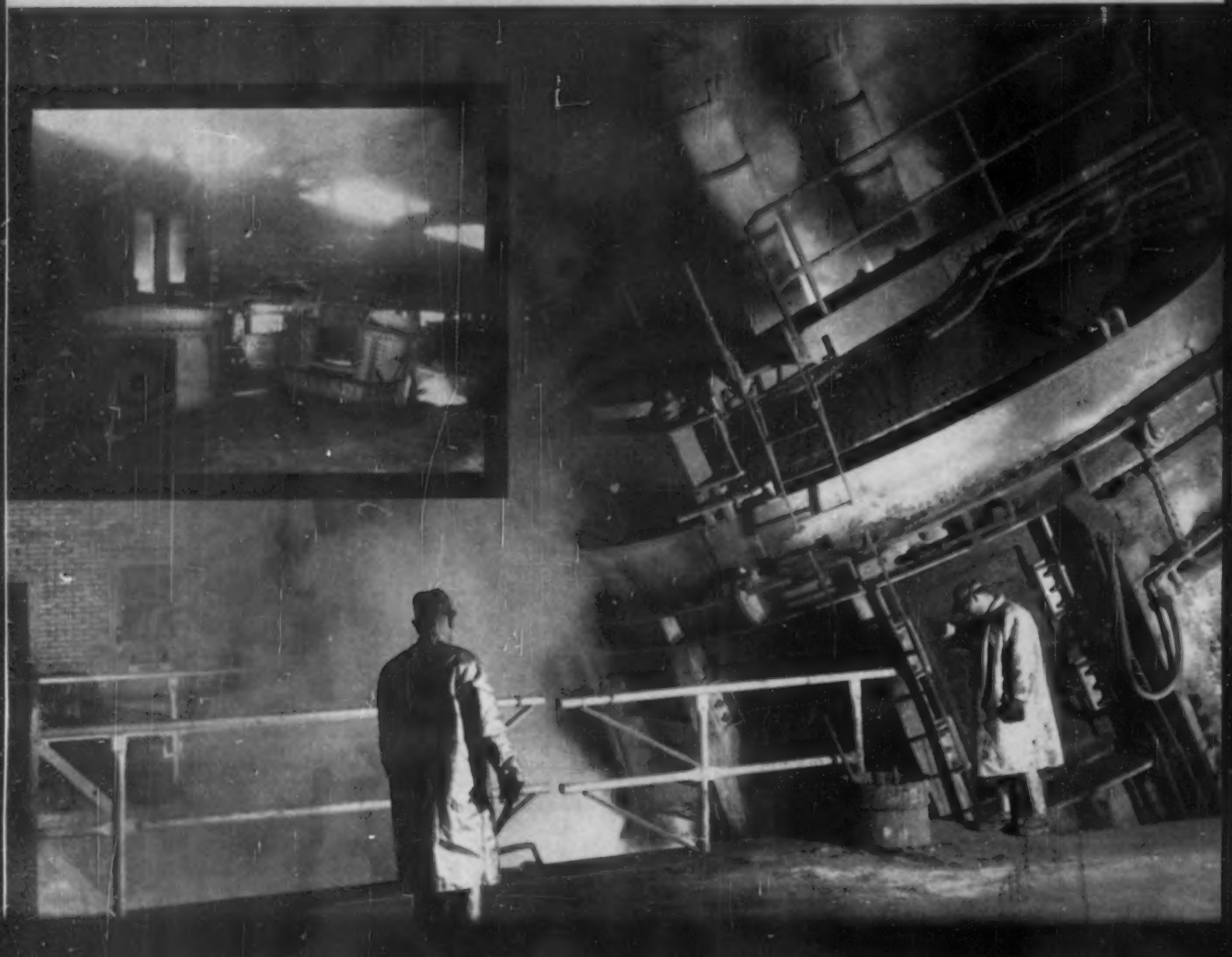

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# NON-METALLIC INCLUSIONS, Their Quantitative Extraction from Steel

*An important factor in steel quality—non-metallic inclusions—can be controlled by steelmaking practices. As a first step in effecting this control, the authors show that quantitative extraction and analysis of non-metallic inclusions in low- and medium-alloy steels is practicable.*

by H. Walz and R. A. Bloom

The type, quantity, and distribution of non-metallic inclusions are prominent factors considered in determining the quality of steels. Since the non-metallic inclusions found in steels are largely the result of the steelmaking practices, the producer is continually working to develop practices that will give improved control of non-metallic inclusions. The purpose of this study was to investigate the possibility of obtaining a complete, quantitative extraction of oxide inclusions from low- and medium-alloy steels.

The procedures for extraction of non-metallic inclusions from steel involve the elimination of the metallic components leaving a residue of non-metallic materials. There are three general residue methods, which may be categorized according to the mode of removal of the metallic components.

**Acid**[1,2,3,4,5]: The acid methods of extraction are dependent upon the solubility of the metallic constituents and the insolubility of the oxides in dilute mineral acids. The various methods of acid extraction differ mainly in the type and strength of the acid used, and do not require special equipment or techniques. These methods appear to be effective only for $Al_2O_3$ and $SiO_2$ and even then there may be appreciable loss of these constituents; therefore, acid extraction is not an adequate means of inclusion study where a complete, unaltered separation is desired.

**Halogen**[6,7,8,9,10,11,12,13,14,15,16,17]: This method of extraction attacks and removes the metallic constituents through the action of halogen elements. The bromine and iodine methods are liquid solution procedures, while the chlorination process consists of treatment in gaseous chlorine at temperatures where the metallic constituents are converted into volatile chlorides leaving the oxides unattacked.

The liquid halogen procedures use either aqueous or alcoholic solutions. The aqueous solutions tend to be acid in character and may result in serious oxide loss. In addition, there may be formation of insoluble hydrates during sample solution. The general extraction procedures consist of solution of the metallic sample, usually millings, with an agitated alcoholic halogen solution in an enclosed reaction vessel. Due to the insolubility of certain alloying elements or their compounds, the alcoholic liquid halogen solution method is most successful with unalloyed, low- and medium-carbon steels.

The chlorine method of extraction had been applied to both alloyed and unalloyed steels with varying degrees of success. The reaction temperature necessary for complete oxide separation is dictated by the sublimation temperatures of the metallic chlorides formed during chlorination of the steel sample. Since the chlorination is an exothermic process, it is difficult to control the maximum reaction temperatures obtained during the chlorine extraction. The chlorine method shows excellent results for plain-carbon and low-alloy steels; however, when treating alloyed steels where non-volatile chlorides, such as chromium chlorides, are formed, the chlorination temperature necessary for complete removal may be high enough to result in chlorine attack on the oxides.

**Electrolytic**[18,19,20,21,22,23]: Electrolytic extraction of non-metallic inclusions consists of anodic solution of the metal sample in aqueous electrolytes where the metal ion is either deposited at the cathode or taken into solution as a complex molecule, and non-metallic inclusions are collected in a residue sludge. The electrolytic methods differ principally in regard

H. WALZ and R. A. BLOOM are with the metallurgical dept., The Timken Roller Bearing Co., Canton, Ohio. This paper is being presented at the 18th Annual AIME Electric Furnace Conference.

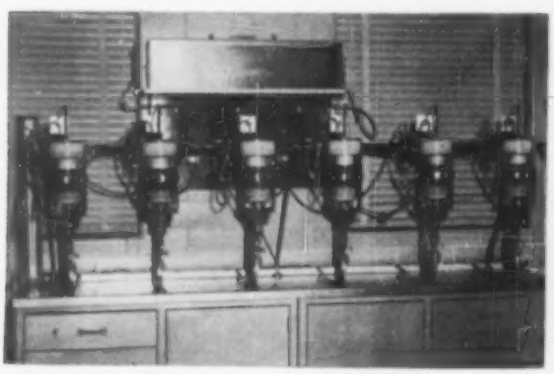


Fig. 1—Electrolytic extraction apparatus.

Fig. 3—Residue chlorination apparatus.

to the choice of electrolyte. Earlier investigators of the electrolytic extraction processes attempted to use a neutral electrolyte because the less-stable oxides are attacked in acid solutions, but the acidity of the solutions varied markedly during the electrolysis, with the resulting decomposition of some of the inclusions. Evolution of oxygen during the extraction caused sample oxidation and contaminated the residue with hydrolization products that formed during the electrolysis. In addition to oxides, the residue sludges may contain carbides, nitrides, sulfides, carbon, and other contaminants which must be eliminated.

The principal difficulty encountered in inclusion extraction is the relative strength of the solvent. When the solvent medium is strong enough to affect complete removal of the metallic constituents in a reasonable time, some of the more soluble oxides are attacked. When the solution treatment is gentle enough to avoid attack on the oxide inclusions, the elimination of the metallic constituents and their alloys is not complete. Electrolytic extraction appeals as a means of separating non-metallic inclusions because its characteristics are more favorable to the retention of non-metallic inclusions than with chemical methods of extraction. However, with electrolytic separation, there must be further purification of the residue in order to obtain a complete isolation of the oxides.

Klinger and Koch[24,25], recognizing the inadequacies of the various methods, devised a scheme involving an electrolytic separation—a modification of the Treje-Benedicks method[26]—followed with a chlorination treatment for purification of the residue. The electrolytic separation employs a flowing buffered electrolyte whereby it is possible to maintain neutrality in the electrolyte during the complete extraction. The buffered electrolyte also acts to form complex ions with the dissolved metal to prevent hydrate contamination of the residue. The residue purification procedure consists of a low-temperature chlorination followed by a high-temperature vacuum sublimation. The elimination of the residue contaminants is possible because the metallics and metalloids in the residue can be made to react with chlorine at temperatures below the chlorine-oxide reaction temperatures for even the less-stable oxides. The subsequent use of vacuum sublimation for removal of the chlorides permits treatment at sublimation temperatures that would result in oxide loss, if chlorine were present. The Klinger and Koch technique was adopted in this attempt to achieve a quantitative extraction of non-metallic inclusions.

The apparatus developed at The Timken Roller Bearing Co. is patterned after that of Blickwede's[27] which is less complicated in design than the original Klinger and Koch apparatus, yet still embodies the same essential characteristics. Fig. 1 is a photograph of the electrolytic extraction apparatus, and the construction of the cell is shown in Fig. 2. The cell consists of two chambers separated by a porous porcelain diaphragm. A fibrous cellulose plastic liner is used inside the porcelain diaphragm to prevent residue contamination from the ceramic diaphragm. The sample, 3.5 in. long, ½ in. diam, is suspended in the inner cell through a lucite cell lid. The anode shaft is insulated from the anolyte with a nylon sleeve, and the residue falling from the sample during electrolysis is collected in the residue dish.

A continuously-flowing electrolyte is used and a constant liquid level is maintained in the inner cell.

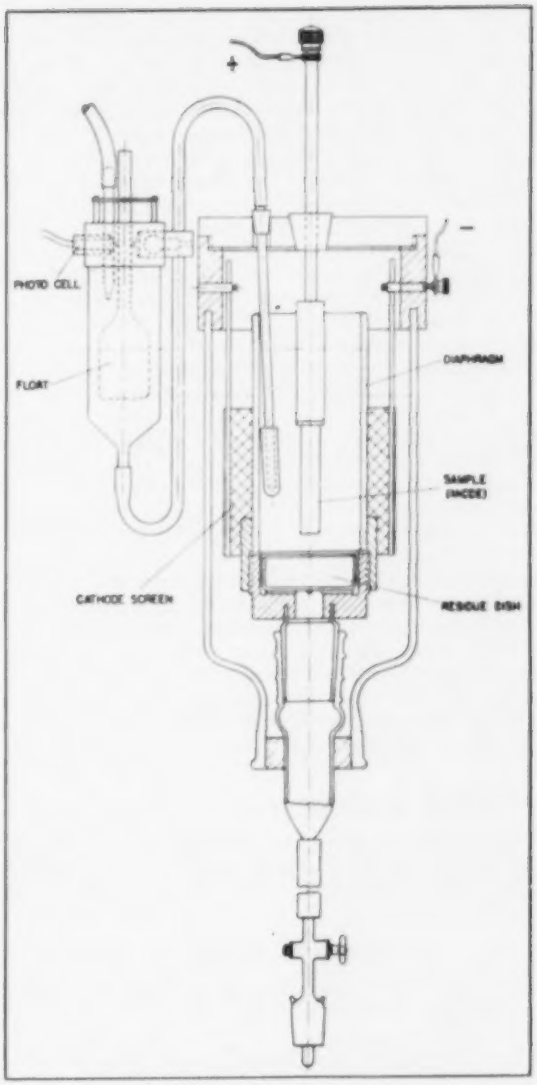
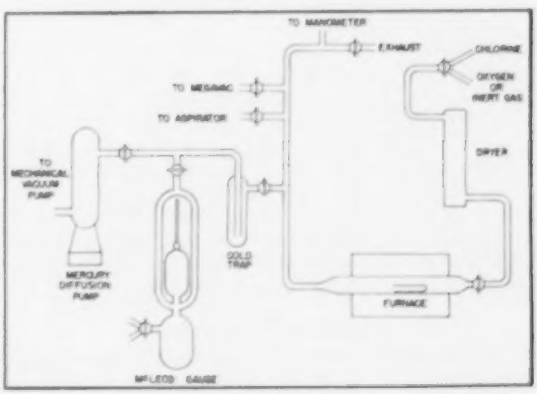



Fig. 2—Above, the electrolytic extraction cell.

Fig. 4—Below, schematic diagram of chlorination apparatus.



A siphon connection to the external liquid level control, consisting of a float and photo cell, energizes a solenoid check valve to add electrolyte from a reservoir. This arrangement maintains the liquid level in the inner cell without disturbing the gravity flow pattern, established by the formation of liquids of higher specific gravity during the electrolysis.

The outer cell contains the catholyte, the cathode screen, and the inlet and outlet for the inert atmosphere used during the electrolysis. The power is obtained from a constant current d.c. power supply with an operating range of up to 4 amp. The cells are connected in series with each cell circuit containing a Zener Diode which shorts out any individual cell that fails to function.

The residue purification apparatus is shown in Fig. 3, and a simplified sketch is shown in Fig. 4. The apparatus consists of a chlorine source, reaction chambers, and vacuum systems. Commercial cylinder chlorine is used with auxiliary equipment for pressure measurement and gas flow control. The reaction chambers are vycor tubes in electric resistance furnaces, operated by indicating controllers. Waxed joints on the furnace tube permit easy access for insertion and removal of the residue tube. The residue combustion treatment is conducted by removing the ground glass joints and passing oxygen through the furnace tube. The operating vacuum is obtained with a mercury diffusion pump. When the system is filled with chlorine, a water aspirator is used in the initial evacuation in order to avoid contamination of the diffusion and mechanical pumps.

## Extraction procedures

The extraction procedure developed is outlined in the diagram in Fig. 5 and, as previously stated, consists of two phases: 1) electrolytic separation and 2) residue treatment.

### Electrolytic Separation

The procedures used may be outlined as follows:

**Sample Preparation:** The specimens are given the following sequence of operations in preparation for extraction: 1) machine, 2) heat treat, 3) grind, 4) clean and weigh, and 5) attach to sample holder.

**Solution Preparation:** A 5 pct sodium citrate, 2 pct KBr electrolyte is used in both cell chambers. Distilled water is used in making the electrolyte which is vacuum boiled and stored under an argon protective atmosphere. Concentrated hydrochloric acid (4 cu cm per amp-hr) is added to the cathode chamber to prevent hydrogen ion depletion resulting in pH build-up in the anode chamber.

**Cell Assembly:** The inner cell is assembled, inserted, the lid attached, the sample holder inserted, the cell purged with argon, the anolyte flow (3 cu cm/min/cell) started and the power (2 amp at 4/6 v per cell) turned on. Except for periodic pH checks, the extraction proceeds unattended for 24 hr. The extraction phase is completed by the removal of the anode which is ultrasonically cleaned, washed, dried, and weighed. The residue from the anode and the anode sludge are combined for further treatment.

### Residue Treatment

The extraction residue is separated and washed repeatedly, first in water and then in alcohol, by centrifuging. While moist with alcohol, the residue is sealed in a combustion tube of the chlorination apparatus. The residues are kept in Vycor tubes throughout, thereby permitting the entire treatment without the necessity of residue transfer.

The purification treatment consists of the following sequences: room temperature vacuum drying, high temperature vacuum drying, chlorination, evacuation, vacuum sublimation, and oxidation. The chlorination-vacuum sublimation sequence may be repeated in order to assure complete chlorination and subsequent removal of the chlorides. The purpose of the oxidation treatment is to burn off the carbon in the residue leaving the oxides intact. The chlorination cycle for the treatment of residues from low- and medium-alloy steels is shown in the diagram of Fig. 6. This treatment is almost identical to that developed by Piper et al.[11] for similar steels. The final residues are weighed and analyzed spectrochemically.

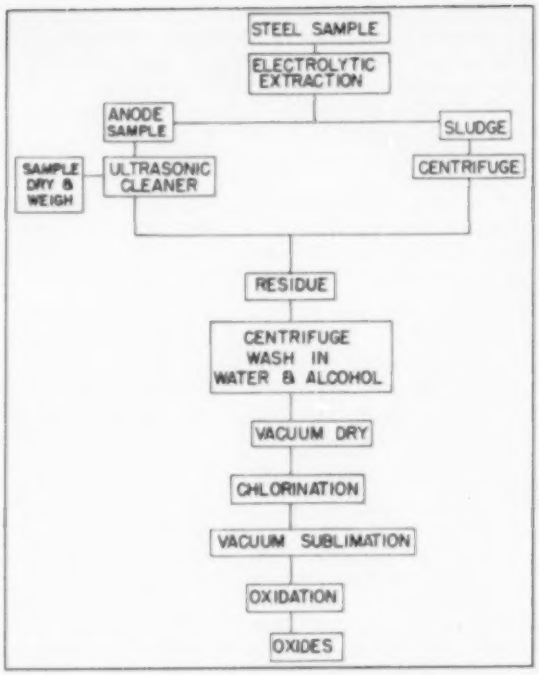



Fig. 5—Above, procedure for extraction of oxide inclusions.

Fig. 6—Below, chlorination cycle for treatment of residues from low- and medium-alloyed steels.

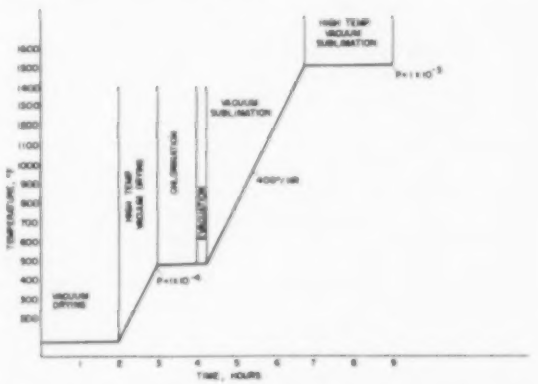


Table I. Analyses Of Ingot Scums Used In Studies Of Extraction And Chlorination Treatments

| Scum Number | Constituent | Ingot Scum Composition, pct | | |
|---|---|---|---|---|
| | | Before Treatment | After Chlorination | After Extraction And Chlorination |
| 1 | $SiO_2$ | 39.0 | 37.1 | 34.0 |
| | $Al_2O_3$ | 30.0 | 28.0 | 36.0 |
| | (FeO)T | 5.0 | 6.4 | 3.6 |
| | $TiO_2$ | .5 | .85 | .6 |
| | CaO | .25 | 1.1 | .2 |
| | MgO | 1.7 | 1.7 | .2 |
| | $Cr_2O_3$ | .25 | .4 | 1.3 |
| | MnO | 22.0 | 22.3 | 18.0 |
| 2 | $SiO_2$ | 18.9 | 33.2 | 21.0 |
| | $Al_2O_3$ | 38.0 | 31.1 | 39.0 |
| | (FeO)T | 10.0 | 8.9 | 16.0 |
| | $TiO_2$ | 1.4 | 1.1 | .9 |
| | CaO | 5.5 | 3.6 | .2 |
| | MgO | 2.0 | 1.7 | .2 |
| | $Cr_2O_3$ | 8.7 | 7.1 | 7.5 |
| | MnO | 15.0 | 14.2 | 14.0 |
| 3 | $SiO_2$ | 17.5 | 25.5 | 27.7 |
| | $Al_2O_3$ | 45.0 | 40.0 | 46.0 |
| | (FeO)T | 7.7 | 8.1 | 6.2 |
| | $TiO_2$ | .93 | 1.0 | .9 |
| | CaO | 5.0 | 4.2 | .6 |
| | MgO | 1.25 | 1.2 | .3 |
| | $Cr_2O_3$ | 1.25 | 1.5 | 1.7 |
| | MnO | 21.0 | 18.3 | 14.2 |

Table II. Effect of Chlorination and Extraction-Chlorination Treatments On Recovery Of Ingot Scums

| Ingot Scum | Recovery, pct | | | |
|---|---|---|---|---|
| | On Chlorination at | | | Extraction And Chlorination |
| | 475°F | 900°F | 1200°F | (475°F) |
| 1 | 99.8 | 100.0 | 99.7 | 95.1 |
| 2 | 99.9 | 101.1 | 100.6 | 95.8 |
| 3 | 99.2 | 97.9 | 96.5 | 95.2 |

## Results

The studies to date have been directed toward the development and evaluation of the outlined apparatus and procedures. The initial studies concerned the effects of the residue treatment using synthetic materials, such as pure oxides, sulfides, and carbides. The resulting data, Figs. 7 and 8, show that a chlorination temperature of 475°F is sufficient for removal of iron carbide. A complete removal of chromium carbide would require a chlorination temperature where there could be appreciable loss of the more reactive oxide constituents, thus verifying the necessity for the low-temperature chlorination followed with the high-temperature vacuum sublimation. The carbide problem is alleviated by the heat treatment of the anode specimen to eliminate or reduce the amount of carbide present. However, where there may be the more stable carbides in the residue, they are given a short, intermediate, higher-temperature chlorination (750°F) to assure complete carbide removal.

The effects of the electrolytic extraction and the residue treatments in the isolation of non-metallic inclusions were investigated by using ingot scums. Both powdered ingot scums and anode specimens containing ingot scums were treated according to the procedures previously outlined. The analysis of the ingot scums used is given in Table I. The results of these studies, Table II, demonstrated that the apparatus and techniques developed should enable a complete oxide isolation. Subsequently, these techniques were applied to the extraction of the non-metallic inclusions from aluminum-killed 1040 and 4340 steels. The analysis of these steels, and the extraction results, along with the oxygen content as

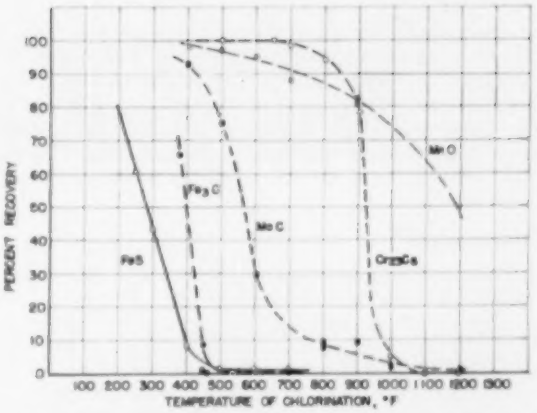



Fig. 7—Effect of chlorination temperature on recovery of FeS, $Fe_3C$, MoC, $Cr_{23}C_6$, and MnO. (Vacuum sublimed at 1500°F following chlorination.)

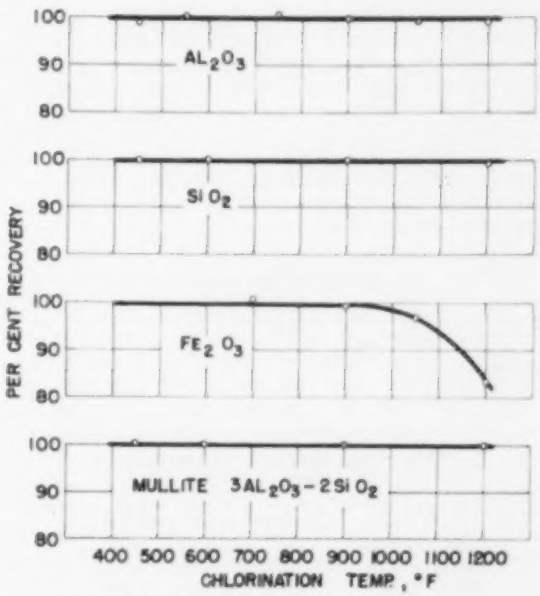



Fig. 8—Effect of chlorination temperature on recovery of some oxides. (Vacuum sublimed at 1500°F following chlorination.)

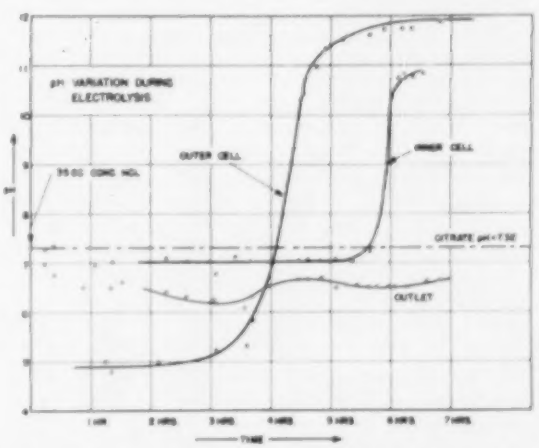



Fig. 9—The pH variation during electrolysis when insufficient acid is added to electrolyte.

determined by vacuum fusion are given in Tables III, IV, and V. The extraction data were used to calculate the oxygen content of steels based on the quantity and composition of the isolated inclusions. The agreement of the calculated oxygen results with those measured by vacuum fusion evidences a complete extraction of the non-metallic inclusions from these steels.

## Discussion

A complete, representative isolation of the non-metallic inclusions is dependent upon prevention of residue contamination as well as complete recovery of the oxides present. Oxidation during the electrolytic and subsequent treatment—one source of contamination—can be avoided through precautions such as the use of degassed electrolytes and a protective atmosphere in the cells, with a minimum exposure of the residues to air during subsequent treatment. The residues are kept moist and are given the chlorination treatment as soon as possible after the extraction has been completed.

Failure to maintain acidity in the cathode chamber can also be responsible for residue contamination. An increase in pH in the inner cell, due to migration of the hydroxyl ions through the porous diaphragm, results in the formation of hydroxides which yield an abnormally high oxide content in the final residue. The pH variation during electrolysis when insufficient acid has been added to the electrolyte is shown in Fig. 9.

Table III. Analyses Of Steels Used In Evaluation Studies—Pct

| Type Steel | Heat No. | C | Mn | Si | P | S | Cr | Ni | Mo |
|---|---|---|---|---|---|---|---|---|---|
| 1040 | 55245 | 0.40 | 0.75 | 0.22 | 0.011 | 0.024 | 0.09 | 0.08 | 0.03 |
| | 23320 | 0.40 | 0.90 | 0.27 | 0.013 | 0.023 | 0.12 | 0.09 | 0.03 |
| 4340 | 68062 | 0.39 | 0.72 | 0.30 | 0.012 | 0.011 | 0.78 | 1.87 | 0.26 |

Table IV. Composition Of Residues Extracted From 1040 And 4340 Steel

| | Residue Composition*, pct | | | | |
|---|---|---|---|---|---|
| Type Steel | $Al_2O_3$ | $SiO_2$ | FeO | MnO | $Cr_2O_3$ |
| 1040 | 82.5 | 13.0 | 2.25 | 0.25 | — |
| 4340 | 80.5 | 19.3 | 0.10 | 0.10 | 0.06 |

*As Determined Micro-Spectrochemically

Table V. Results Of Extraction Of Non-Metallic Inclusions From 1040 And 4340 Steels

| Type Steel | Heat No. | Investigation No. | Extraction Residue Wt (gm) | Pct | Oxygen, pct Calculated | Vacuum Fusion |
|---|---|---|---|---|---|---|
| 1040 | 55245 | I | .0027 | .0132 | .007 | .006 |
| | | | .0033 | .0162 | .008 | |
| | | | .0023 | .0112 | .005 | |
| | | | .0020 | .0098 | .005 | |
| | | II | .0026 | .0108 | .005 | .006 |
| | | | .0024 | .0099 | .005 | |
| | | | .0028 | .0116 | .006 | |
| | | | .0028 | .0115 | .006 | |
| | 23320 | I | .0026 | .0056 | .003 | .002 |
| | | | .0028 | .0061 | .003 | |
| | | | .0029 | .0063 | .003 | |
| 4340 | 68062 | I | .0042 | .0088 | .004 | .003 |
| | | | .0043 | .0090 | .004 | |
| | | | .0051 | .0106 | .005 | |
| | | | .0052 | .0106 | .005 | |
| | | II | .0040 | .0094 | .005 | .003 |
| | | | .0040 | .0084 | .004 | |
| | | | .0046 | .0097 | .005 | |
| | | | .0042 | .0089 | .004 | |

Quantitative analysis of the residue presents a problem because the amount of residue that is feasible to extract and handle with this equipment is extremely small. Conventional chemical analytical methods were not applicable, therefore, microspectrochemical methods are used. Even with these techniques it is necessary to combine residues in order to obtain sufficient quantity for a reliable analysis. Particular care must be taken in handling these minute residues to avoid contamination.

The results of the studies with the apparatus and procedures described show that a quantitative extraction and analysis of the non-metallic inclusions in low- and medium-alloy steels is practicable. Additional studies are in progress to extend these techniques to the more highly alloyed steels. Quantitative data concerning the amount and composition of the non-metallic inclusions in steels will be a valuable aid in the further development of steelmaking practices for the production of high quality electric furnace steels.

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# A customer surveys, RELIABILITY FACTORS IN STEEL USAGE

Extracted from a paper
by H. Thomas Hallowell, Jr.

In this atomic age there is a growing need for better steel. There are about 50 million grains in 1 cu in. of steel which has a grain size of no. 5. Each of these individual grains has a composition of atoms; it has boundaries and is in a certain relation to its neighboring grains. I have no comment to make about the basic atoms because, try as we will, we can't change them when we make steel. The problem seems to lie in what we put in the grains—how we make them— how we make assemblies of these grains in ingots, casting, forgings, or rolled shapes.

While a small iron whisker has a tensile strength of 2 million psi, just why are we so inefficient that common steel has about 100,000 psi tensile—5 pct of the potential of pure iron? When we take into account a factor of safety of say five, we get a design value of 20,000 psi or about 1 pct of the 2 million psi.

But times have changed and the steel hasn't—at least not very much! We no longer can afford to use the great weight or mass and the unnecessary size that goes with great mass. One hundred years ago the solution to a problem on a railroad was to make the section heavier and use more material and whatever space was needed. Costs were low, labor cheap, speeds slow, and competition was quite leisurely. And we were still fighting the Indians!!

Today, with the cold war, extremely high costs of everything—especially labor—unbelievably keen world-wide competition, and with speeds getting up to those required for space travel, we're forced to do a complete about-face in our ideas on the use of mass and volume. In our latest designs we can no longer *play it safe* because if we do, we won't live!

We're rapidly being forced to use to a greater proportion the potential properties of metals. Weaknesses are now appearing, because we've changed the rules of the game. What used to be acceptable in performance simply won't do the job of today. In other words, we demand a degree of reliability that is sufficiently high so that our assemblies will do the job required. If we have 100 components in our assembly, and each component comes from a lot that is 99 pct ok (1 out of 100 defective), then we only get 36 pct good assemblies. Change the component reliability to 98 pct instead of 99 pct and only 13 pct of the assemblies will work—96 pct decreases the assembly performance to 1.6 pct! Or go the other way—if 410 parts of an assembly each come from lots that are 99.44/100 pct reliable, only one out of 10 of the resulting assemblies will satisfactorily perform!

In order to cope with this new way of life we have become extremely suspicious and critical of any lot of steel. Each lot of incoming material is checked in great detail. We can't live with seams, cracks, pits, porosity, pipes, inclusions, variable grain size, poor annealing, decarb, woody structure, high hydrogen content, and poor susceptibility to plating. We keep complete, detailed inspection and performance records of every lot of steel received.

The very dramatic increases in the specifications of our latest high-strength fasteners have been brought about by the most exacting attention being paid to each element in which there could be a variation—and this variation minimized. The critical areas of the present generation of missiles are now held together with tension threaded fasteners that have a minimum strength of 260,000 psi, with an elongation of more than 10 pct. Our newest types of planes also require these high-reliability fasteners. We are now about to introduce a 300,000 psi threaded fastener with a fatigue strength that has a proportional increase with the tensile value. This is double the strength of the 125,000 psi bolts of 10 years ago. But 2 million psi is the ultimate aim, and we're now marketing 300,000 psi. Give us a little time in the future, and we'll be a lot higher! But to do these things, each of the 50 million grains in each cubic inch of steel must be right!

In addition to this need for higher strength materials, we are constantly being pressed for higher reliability. Take the case of the Atlas Intercontinental ballistic missile, reputed to have 300,000 separate components. What must be the average reliability of each of these parts—assuming all are vital to success—in order to put the Atlas on target nine times out of ten—not too high a goal in this day of sudden-death warfare. Well, each part has to have a reliability for the mission of 99.99996 pct! Here even Ivory soap purity fails us. If the Atlas' 300,000 parts each had a reliability of only 99.44/100 pct, they would never get a single missile to the mark. The resulting overall reliability would be an infinitesimal fraction—a decimal point followed by 731 zeroes and then a 2!

The recent 12-month warranty on our new automobiles is going to make a great change in our way of life. Cracked nuts on engine connecting rod bolts —for a saving of 10¢ per 1000 units—will not be a good investment for anyone connected with the deal —the steel supplier, the manufacturer of the nuts, the purchasing agent, the receiving inspection department, or the company who would dare to put such a shoddy end product in the hands of the public.

I encourage you to give some thought to the steel you make and realize that one way or another it must be better tomorrow than it is today. Highly reliable steel is the only kind we can afford to buy because that's the only kind we can live with. Just 50 million good grains in each cubic inch of steel!

H. THOMAS HALLOWELL, JR. is president, Standard Pressed Steel Co., Jenkintown, Pa. This paper is being presented at the 18th Annual AIME Electric Furnace Conference.

# ON ENGLAND'S LARGEST ELECTRIC FURNACE PLANT

*England's largest electric furnace shop—now under construction—will replace a 1-million-ton-per-year open-hearth shop built some years ago. This project is part of United Steel Companies program for installing 100-pct hot-metal charged Ajax furnaces at one plant and 100-pct cold-charged arc furnaces at another plant.*

by R. S. Howes, and A. Jackson

A new electric arc furnace plant is being built at the Steel, Peech and Tozer works near Sheffield, England. This works is one of the four separate steelmaking branches of United Steel Companies Ltd. These four works are integrated to a degree, although only one branch, the Appleby-Frodingham Steel Co. in Scunthorpe, is directly and closely involved in the Steel, Peech, and Tozer project.

As United Steel's capacity is not less than 14 pct of the total UK ingot production, the ratio of usage of pig iron to scrap must necessarily be closely related to the national average. The company aims to be self sufficient in pig iron, and for many years has adjusted its iron production with this aim in view. The principal pig-iron producer is the Appleby-Frodingham works, where phosphoric iron is made entirely from a self-fluxing mixture of domestic ores. Although the ores are very low grade, averaging 26 pct Fe before sintering, the iron cost is relatively low in relation to most other producers. Its analysis is shown in Table I.

Of the steelmaking plants, Appleby-Frodingham at Scunthorpe has used molten phosphoric iron and its own circulating scrap in large tilting furnaces (see Table I, col. 1). Steel, Peech and Tozer obtains 37 pct of its steelmaking materials from Scunthorpe as machine-cast pig iron, the remainder being circulating and merchant scrap. The plant has two melting shops containing a total of 21 cold-charged fixed open-hearth furnaces, most of which tap 123 tons of ingots, while the remainder are 73-ton capacity.

The integration of these separate branches within United Steel Companies Ltd, and the necessity of maintaining a balance of steelmaking materials, both within the company and nationally, meant that major chances in steelmaking technique must be considered in a much wider field than that of a specific branch.

## Reconstruction plans

Owing partly to the age of the plant and to the increasing efficiency of competitive steelmaking processes, it became necessary to consider how the 21 cold-charged furnaces at Steel, Peech, and Tozer could be replaced by more economic operating units. Table I, col. 2 shows the raw materials and general operating characteristics for a steel quality group which covers a large percentage of the total ingot production. In this same context it is important to note comparable factors in steelmaking at Appleby-Frodingham (some 45 mi away) because this had an important bearing on the problem under consideration, (Table I, col. 1). It should also be noted that the overall usage of steelmaking metallic raw materials in these two plants must continue in the same total ratio, i.e. a change in the usage in one plant would call for an opposite change in the other.

Various possible solutions to the problem of replacing Steel, Peech, and Tozer's melting shops were considered and rejected. These included installing a plant to make the ingots in Scunthorpe by oxygen blowing processes, or supplying molten iron to Sheffield, but finally electric furnaces installed in Sheffield appeared to provide the most economic replacement.

The obvious plan was to consider melting in large arc furnaces the open hearth mixture already in use in the open hearth furnaces and removing carbon by oxygen lancing. Careful investigation showed that such a process could give some savings over the existing cold-charged open-hearth practice. If, however, one considered the improvements possible in the existing open-hearth plant, (such as the application of basic roofs, oxygen for combustion, multiple burners, etc.) then the prospective savings were so reduced that it was difficult to see a satisfactory return on the new capital necessary to replace a plant already largely written off.

At this time Appleby-Frodingham was beginning to obtain results on its Ajax oxygen open-hearth process, which was proving to be more economic using 100 pct hot metal than the traditional process using 76 pct molten metal and normal circulating scrap. As soon as this process was proved to a reasonable degree, it brought forward a significant new possibility, i.e. sending Appleby-Frodingham circulating scrap to Sheffield instead of cold pig iron so that the electric furnace could operate on close to 100 pct scrap. This obviously reduced slag volume and provided such an increase in production rate that the projected seven furnace plant could be reduced to six furnaces.

The revised raw materials distribution can be seen in Table I, col. 1 shows the former standard open-hearth practice at Appleby-Frodingham, which gave optimum results. The Ajax process figures, shown in col. 3, are based on the last 224,000 tons of ingots produced, and show a considerable improvement on the early practice. The arc furnace figures, col. 4, are derived a) from work on Steel, Peech,

R.S. HOWES is with Steel, Peech and Tozer, while A. JACKSON is with the Appleby-Frodingham Steel Co., both of the United Steel Companies. This paper was presented at the 1960 Journée du Four á Arc electrique de fort Capacité at Liège, Belgium. It appeared in the Revue Universelle des Mines, Sept. 1960 and the Journal of The Iron and Steel Institute, May 1960.

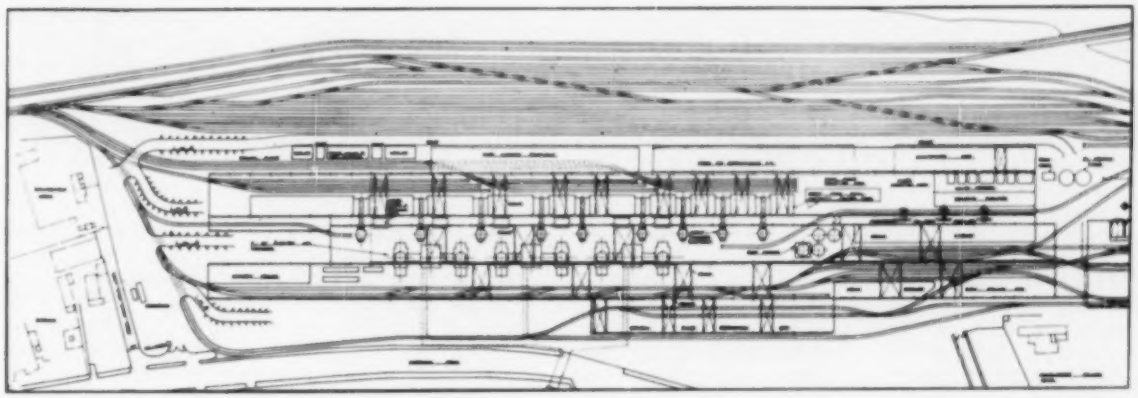
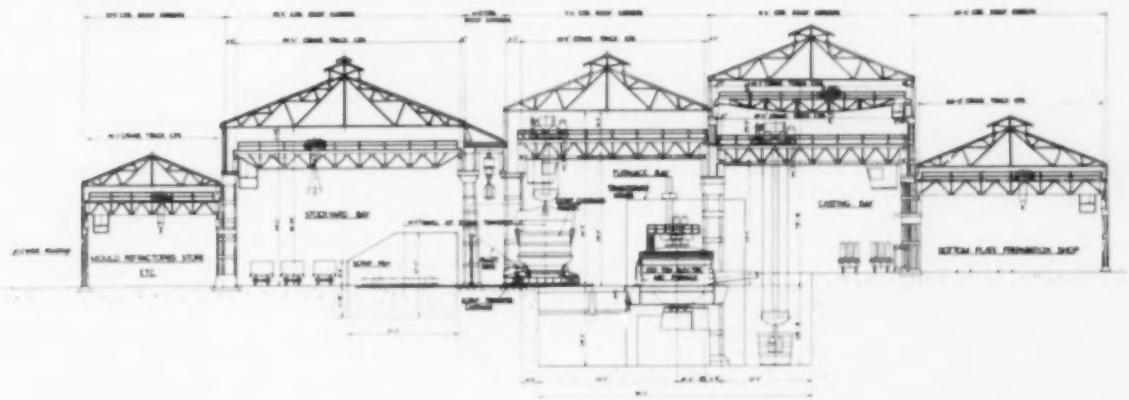


Fig. 1—Above, proposed layout of the new Steel, Peech and Tozer electric melting shop. Fig. 2—Below, cross section through melting shop.



and Tozer small arc furnace, b) from published information, and c) were confirmed as fully as possible by operating a 90-ton arc furnace for a month using the proposed Steel, Peech, and Tozer mixtures and making the types of steel required.

## Comparison of steelmaking methods

To make a comparison between former practice using open-hearth furnaces in both Appleby-Frodingham and Steel, Peech, and Tozer melting shops with the proposed Ajax process at the former and electric arc at the latter, the following assumptions are used:

a) of the total ingots produced by the two plants about 58 pct has been produced at Appleby-Frodingham and 42 pct at Steel, Peech and Tozer; it is assumed that this ratio will remain constant; and

b) the use of 100 pct molten iron in the Ajax process and 100 pct scrap in the arc furnace, although a small degree of interchange is practicable.

**Raw Materials:** The figures show that the use of open-hearth furnaces at both plants requires a total of 61 pct pig iron, while the new method requires 61.5 pct. The ingot yield calculated on charged pig iron, scrap, and Fe from ore is 88.54 pct and 89.46 pct respectively, a gain of 0.92 pct.

**Fuel:** If the costs of fuel, oxygen for lancing and combustion, electrodes, and power (arc furnace only) are compared, there is no significant difference between old and new practice, taking the two plants together.

**Production Rate:** The production per operating furnace increased by over 80 pct using the Ajax process and by 350 pct from the new arc furnaces, thereby giving considerable reduction in operating costs.

**Refractory:** Refractory brick consumption and fettling dolomite show marked reduction in costs.

**Slag and lime:** The total lime consumption and slag volume produced have fallen. However, more slag is made in the Ajax furnaces, and it contains a higher phosphoric acid content than formerly. This arises because the phosphorus which was formerly sent to Steel, Peech and Tozer and discarded with their slag is now retained at Appleby-Frodingham and sold as fertilizer.

## The New Electric Melting Shop

When conversion plans are complete, the plant will consist of six 24-ft diam electric arc furnaces, each tapping 123 ingot tons. Each furnace will be powered by a 40,000 kva transformer and fitted with 24 in. diam graphite electrodes. A plan of the complete shop is shown in Fig. 1 and a cross-section through the furnaces in Fig. 2.

The site at the present time is occupied by Templeborough melting shop, which produces 1,010,000 ingot tons annually from 14 fixed cold-metal open-hearth furnaces. Since the new shop is designed to produce over 1,520,000 tons annually, considerable modification has had to be made in the raw material handling facilities, the casting pit, and stripping area, as well as the furnace bay. The following notes give a brief description of each section of the shop.

**Layout of railways:** To handle the greatly increased amount of scrap that will be required by

this melting shop, a very extensive marshalling yard has been laid out behind the raw material stockyard. This marshalling yard has sufficient capacity to store a 24-hr supply of raw materials.

**Raw material stockyard:** The problem of filling electric-furnace charging baskets is very different from and in some ways much simpler than, filling open-hearth charging boxes. The stockyard has been arranged with nine basket-filling stations, each served by its own magnet crane. These stations are arranged in groups of three, each group being served by its own railway line and containing scrap pens as well as wagon standing room. These scrap pens have a capacity of 27,000 tons and are intended to smooth out fluctuations in the flow of incoming raw materials and to provide against interruptions due to bad weather, etc. Thus, it can be seen that the raw material stockyard and marshalling yards together hold nearly a week's supply of raw materials.

Between the stockyard bay and the furnace bay is a narrow building at present housing the open-hearth furnace chimneys. Advantage is being taken of this small bay to provide storage bunkers for oxides, fluxes, and fettling materials, storage bunkers being filled by an overhead monorail crane.

**Furnace bay:** The open-hearth stage will be completely removed and the arc furnaces installed at ground level with a transformer house between each pair of furnaces. The columns lining each side of the furnace bay will require extensive modification in order to withstand the increased loading of the three new basket-charging cranes, each of 168 tons capacity. Slag removal from the furnace will be by road vehicle through an underground tunnel, emerging at the western end of the shop.

**Casting pit:** Very little alteration will be made to the existing casting pit apart from some re-organization of the railways and mold cooling gantries. The present casting cranes, of which there are four of 168 tons capacity, will be adequate for the electric shop. At the west end of the shop, special arrangements will be made for producing forging ingots from 3 to 110 tons, both by conventional and vacuum casting. At the other end of the casting pit slow-cooling facilities are provided for alloy and other crack-susceptible steels.

**Shop production:** The bulk of the shop production is plain carbon and rimming steels for billet, bar, rod, and strip mills, but smaller tonnages also have to be provided for wheel mills and the press and hammer forges.

**Fume cleaning:** To meet the requirements of the new clean air legislation, the furnaces will be equipped with an extensive fume cleaning plant. Although the design of this has not yet been finalized, it will probably consist of direct extraction through the furnace roof, a spray conditioning chamber, and electrostatic precipitators.

Table I. Comparison of Processes

| | Present practice | | Future practice | |
|---|---|---|---|---|
| | Appleby-Frodingham OH | Cold-charged OH | Ajax process | Electric arc |
| Hot metal, lb per ton | 1495 | nil | 2120 | nil |
| Cold pig, lb per ton | nil | 840 | nil | nil |
| Scrap, lb per ton | 570 | 1395 | nil | 2142 |
| Finishings, lb per ton | 20.5 | 18 | 21 | 18 |
| Pit scrap, lb per ton | 87 | 80 | 75 | 54 |
| Ore, lb per ton | 224 | 54 | 173 | 18 |
| Slag made, lb per ton | 242 | 425 | 300 | 153 |
| Limestone, lb per ton | 125 | nil | 100 | nil |
| Lime, lb per ton | 12 | 167 | 52 | 76 |
| Fluorspar, lb per ton | nil | 19 | nil | 14 |
| Dolomite, lb per ton | 67 | 76 | 58 | 20 |
| Fuel, Btu x $10^6$ | 4.07 | 5.36 | 0.8 | nil |
| Oxygen, lancing, cu ft | nil | nil | 1125 | 134 |
| Oxygen, combustion, cu ft | 92 | nil | 134 | nil |
| Power, kw-hr | — | — | — | 468 |
| Electrode, lb | — | — | — | 9.3 |
| Production, tph | 17.6 | 10.0 | 32.5 | 33.0 |
| tons per furnace week | 2960 | 1680 | 5460 | 5550 |
| Availability, pct | 89.8 | 85.5 | 91.0 | 94.5 |
| Brick consumption | | | | |
| Silica, lb | 23.33 | 40.0 | 1.11 | 8.93 |
| Firebrick, lb | 2.92 | 22.0 | 1.19 | — |
| Magnesite, lb | 1.86 | 0.2 | 0.85 | 9.37 |
| Chrome-magnesite, lb | 5.25 | 11.7 | 12.08 | — |
| | 33.36 | 73.9 | 15.23 | 18.30 |
| Tapping capacity, tons | 336 | 123 | 224 | 123 |

| | C | P | Mn | S | Si |
|---|---|---|---|---|---|
| Cold pig iron analysis, pct | 3.65 | 1.35 | 0.90 | 0.050 | 0.65 |
| Mixer metal analysis, pct | 3.4 | 1.15 | 0.40 | 0.045 | 0.25 |

## Steelmaking

The bulk of the steel qualities will be made using a single-slag technique from a charge consisting of 100 pct scrap with sufficient anthracite to give a 0.40 pct carbon boil.

To achieve the stated output it will be necessary to receive 33,500 tons of scrap per week, 8,400 tons of this will be circulating scrap from the plant itself, upwards of 11,200 tons per week will come from the Appleby-Frodingham works, and the remainder will be bought merchant scrap. As has been previously stated, this leaves the United Steel Companies' overall balance of materials unchanged, the figures being in accordance with the national averages.

For the alloy qualities at present made by the acid open-hearth process, and for steels of conventional electric quality, a short reducing slag period will probably be necessary thereby giving a double-slag practice. In cases where low gas content is important, it may well prove advisable to revert to a bath or even ladle finishing. For extreme cases, and certainly with heavy forging ingots, vacuum casting presents a proven means of producing low-hydrogen steels.

Table I, col. 4 give details of the furnace performance figures that are expected. These are largely self-explanatory, but it is perhaps worth noting that the average output rate is given as 33 tons per hr. This is a composite figure based on the qualities it is expected to make. For the bulk of the production 37 tons per hr. is anticipated, i.e. a furnace cycle time of 3 hr 20 min, tap-to-tap. With the exception of forging ingots, which will be floor cast in sunken pits, the entire production will be car cast, the majority being uphill teemed.

## Conclusions

When completed, the new electric melting of Steel, Peech, and Tozer will produce the equivalent of 6 pct of the present UK ingot production, and double the existing electric steelmaking capacity.

By changing from open-hearth steelmaking with hot metal in tilting furnaces and cold-charged fixed furnaces to the Ajax process using hot metal and the arc furnace using cold scrap, significant cost savings can be made. Since the same utilization ratio of scrap to pig iron is retained, it is unnecessary to include the relative prices of scrap and pig iron in assessing the total proposals for the two steelmaking plants concerned.

[In a future issue, JOURNAL OF METALS expects to publish the latest information available on the operation of the Ajax process, thereby completing the picture of his two-fold modernization program. (Ed.)]

# Technology of DWIGHT-LLOYD MCWANE IRONMAKING

*Hot, carbonized pellets, produced as highly beneficiated feed, are smelted in a conventional submerged-arc furnace. Electrical energy requirements decreased more than one half, while furnace productivity more than doubled over that of normal practice.*

Summary of a paper
by T. E. Ban and B. W. Worthington

Iron has been produced by electrothermal reduction for a number of years in geographical regions with low-cost electrical energy and high-cost metallurgical coke. The conventional operation is performed by continuously charging ore, flux, and reductants into a submerged-arc electric furnace.[1, 2, 3, 4, 5] Underneath the electrodes, the molten products collect to form a pool, which is tapped periodically. Gases, containing 70 to 80 pct CO, ascend through the short porous column of the charge and are collected in off-takes. The furnace, illustrated in Fig. 1, is typical of units that range in capacity up to 24,000 kva with iron production as high as 220 tpd.[6]

Some prominent metallurgists have reasoned that the over-all efficiency of this type of smelting was subject to improvement because of two unique characteristics:[7, 8] 1) the short stack column does not necessitate the use of high-quality reductants, and 2) high crucible temperatures give rise to rapid smelting rates and influence the production of high-calorific furnace gases. Benefits of pre-heated and pre-reduced charges for conventional furnaces have been given by several authors.[7, 8, 9, 10] In cases of impervious or difficult-to-smelt burdens, open-arc furnace applications have been applied.[11, 12]

Early in 1948, McWane Cast Iron Pipe Co. sponsored an investigation of the economic production of foundry-grades of iron at relatively small production rates. Short-stack blast furnaces and hot-blast cupolas were considered, as well as modified systems for electric smelting furnaces. The program culminated in the perfection of the Dwight-Lloyd McWane process (D-LM), a novel method of producing cast iron by using a composite charge of highly beneficiated feed for the submerged-arc electric furnace. Preliminary research at Battelle Memorial Institute and numerous documented pilot-plant campaigns at Dwight-Lloyd research laboratories have adequately demonstrated the applicability of the flowsheet used extensively for evaluation and development.

The D-LM process consists of the continuous smelting of carbonized pellets. Raw materials are blended, ground, and balled into green-pellets. These are dried and ignited to initiate carbonization, which includes coincidental combustion, reduction, and agglomeration, and results in a highly-beneficiated feed for subsequent smelting. Control of green-pellet composition and carbonizing draft rates is sufficient to maintain ample residual carbon for completion of endothermal smelting and carburization of the metal. Ordinarily, smelting conditions are controlled for producing gray foundry iron, but the system has adequate flexibility for the manufacture of silver, white, basic, and low-carbon pig irons.

T. E. BAN is vice president-research, McDowell Co., Cleveland, and B. W. WORTHINGTON is director of research, McWane Cast Iron Pipe Co., Birmingham, Ala. The original paper was presented at the 1960 Fall Meeting of The Metallurgical Society.

## Pilot Plant

Coal, ore, and limestone, similar to the analyses shown in Table I, are automatically proportioned for a metallurgical burden and then ground to −20 mesh in an open-circuit ball mill. Fine grinding provides a suitable structure for balling, and increases chemical reactivity in the carbonization process. A 7½-ft Flying Saucer® balls the wet fines into ¼ to ¾ in. diam green pellets, containing about 15 pct moisture. Results indicate that a ⅜ to ½ in. diam range is most desirable for the process.

Green pellets are continuously fed to a 2x16-ft down-draft Dwight-Lloyd machine for drying and carbonization. The wet charge is dried with the recycled waste gases controlled to expel moisture without spalling or pre-igniting the balls. After drying, ignition with a gas torch starts the reaction, and either air or recycle draft is used to support combustion. Reactions occur both in the pellet bed and within the individual pellets: carbonization of coal to coke produces hard pellets with a hydrocarbon volatile content of about 1 pct, and favorable bed conditions exist for catalytically converting hydro-carbons into reducing gases. Composition of the carbonized pellets, shown in Table I, indicates that $Fe_2O_3$ is substantially reduced to FeO with a portion being reduced to metallic iron.

Typical gradients of composition through the cross-section of a pellet, Fig. 2, illustrates some unique properties beneficial to charge resistivity. The outer zone is highly oxidized in comparison with the inner zone, and the central zone is reduced to a lesser extent. The surface is exposed to the

oxidizing air draft, the core is subject to lower reduction temperatures, and a diffusion of reducing gases apparently merges with a high-temperature wave to provide strong reducing conditions in the inner zone; thus, the existence of the forementioned gradients appears reasonable.

Red-hot pellets, approx 2000°F, are discharged from the DL machine as self-fluxing, self-reducing charge. These pellets are screened and elevated to a choke-fed hopper which continuously charges the 500 kva smelting furnace in the center of three delta arranged electrodes. Myriads of buried arcs form within the carbon layer which floats on the molten slag, thus allowing the generated carbon monoxide to react with the pre-heated pellet charge. As melting progresses, the furnace is tapped, slag is removed from the ladles, and the metal is cast in a series of cascading pig molds.

## Evaluation

A research program designed to evaluate the iron ore burden for the conventional electric vs the DLM process, was carried out at the Dwight-Lloyd research laboratories. A direct-shipping hematite ore—Champion Fines—was converted into fluxed sinter for a one-week smelting campaign by the conventional electric-furnace process, and the remaining ore was used directly in a similar campaign by the D-LM process. In order to use comparable reductants, coke of an ash content similar to that of the carbonized coal in the pellets was used. Since the same smelting facilities were used for both processes, the principal differences were related to feed preparation.

Advantages of the highly-beneficiated charge used in the D-LM process are illustrated in Figs. 3 and 4. Productivity was practically doubled, while electrical energy and electrode consumption were reduced approx 50 pct, despite the higher silicon iron in the process. Comparison of the carbon dioxide content of the furnace gases, as an indication of indirect reduction, showed that the D-LM process contained 32 pct $CO_2$ as against 13 pct for the conventional process.

Heat balances and furnace efficiencies, shown in Table II, are derived from separate operations which produced slightly different grades of metal. Translation of these data to common slag volumes and iron grades show a remarkable correlation for conventional processes which substantiate pilot-plant scale-up factors. It is apparent that D-LM pig iron containing 1 pct Si, with 600 lb of slag volume would have an electrical energy requirement less than 900 kwh per net ton of iron (NT PI).

Intrinsic to the D-LM process are several noteworthy features:

1) substitution of ordinary non-coking coals for metallurgical coke;

Table I. Chemical Analyses of Raw Materials Used for Dwight-Lloyd McWane Process Evaluation

| | Iron ore | Coal | Limestone | Carbonized Pellets |
|---|---|---|---|---|
| Moisture | 2.3 | 7.0 | 4.4 | 0.0 |
| Analyses (Dry) | | | | |
| $Fe_{total}$ | 58.7 | | | 49.8 |
| $Fe_2O_3$ | 82.0 | 2.0 | | 3.0 |
| FeO | 1.7 | | | 43.5 |
| $Fe_{metallic}$ | | | | 13.8 |
| $SiO_2$ | 10.3 | 5.2 | 3.6 | 10.7 |
| $Al_2O_3$ | 3.9 | 2.5 | .7 | 4.2 |
| CaO | .6 | .4 | 30.5 | 9.7 |
| MgO | .1 | .1 | 12.2 | 2.9 |
| Mn | .1 | | | |
| S | .2 | .6 | .2 | .3 |
| LOI | 1.0 | | 44.2 | 2.7 |
| FC | | 53.0 | | 9.1 |
| VM | | 35.8 | | |

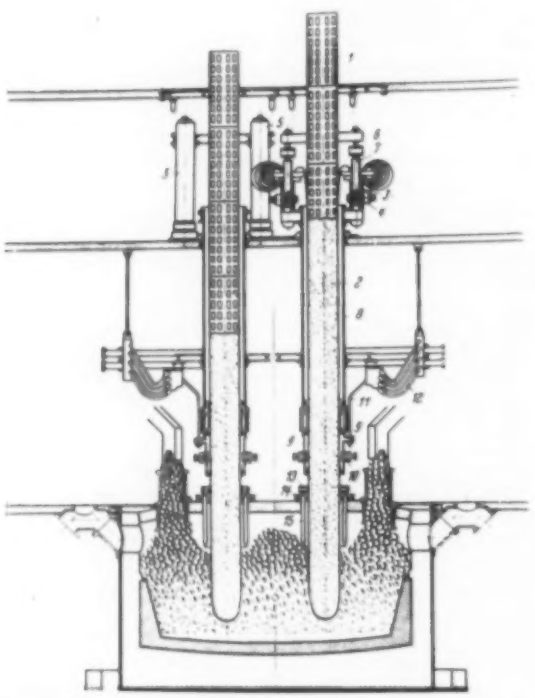


Fig. 1—Conventional smothered-arc electric iron-smelting furnace.[1]

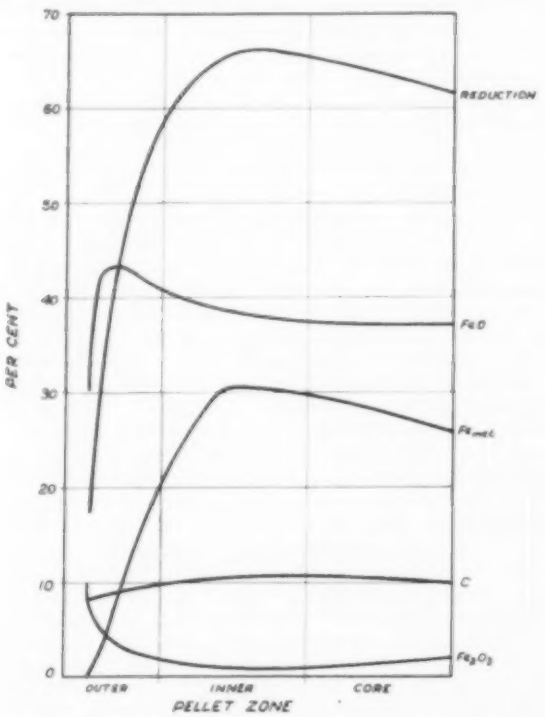



Fig. 2—Typical composition gradient of carbonized pellet.

Table II. Heat Balances and Electric Pig Iron Furnace Efficiencies Commercial, Pilot Plant, and D-LM Pilot Plant Operations

| | Conventional Electric Furnace Practice (3.60 pct C, 1.80 pct Si, 0.03 pct S) Commercial | Conventional Electric Furnace Practice (3.04 pct C, 1.03 pct Si, 0.17 pct S) Pilot Plant | D-LM Practice (3.72 pct C, 2.43 pct Si, 0.03 pct S) Pilot Plant |
|---|---|---|---|
| Heat Input | Btu NT PI | Btu NT PI | Btu NT PI |
| Reduction: $Fe_2O_3$, $Fe_3O_4$, FeO, $SiO_2$, $P_2O_5$, $MnO_2$ | 6,197,000 | 6,050,000 | 3,527,200 |
| Calcination: Mg $CO_3$, $CaCO_3$ | 114,000 | 261,000 | 168,000 |
| Evaporation: $H_2O$ | 75,000 | 54,000 | |
| Heat content above datum: slag, iron, gas | 1,872,000 | 2,513,000 | 1,506,600 |
| Total | 8,258,000 | 8,878,400 | 5,201,800 |
| Heat Output | | | |
| Heat of slag formation | 60,500 | 138,000 | 355,000 |
| Oxidation: C to CO | 2,252,000 | 2,239,000 | 820,000 |
| Oxidation: C to $CO_2$ | 607,000 | 607,000 | 1,098,000 |
| Total | 2,919,500 | 2,984,000 | 2,273,00 |
| Net Heat Requirement, Btu | 5,338,500 | 5,894,400 | 2,928,000 |
| Theoretical kw-hr/NT Pig Iron | 1,563 | 1,726 | 858 |
| Actual kw-hr/NT Pig Iron | 1,800 | 2,368 | 1,221 |
| Efficiency-pct | 82.3 | 72.9 | 70.3 |
| Corrected to Common Product (1000 lb Slag, 2 pct Si—kw-hr/NT PI) | 2,052 | 2,356 | 1,178 |
| Corrected to Common Product & Efficiency (1000 lb Slag, 2 pct Si, 82.3 pct Eff.—kw-hr/NT PI) | 2,052 | 2,087 | 1,004 |

2) green pellet strength comparable to that of taconite attained by using coarser mesh materials;

3) extremely rapid carbonizing reactions within the bed of the Dwight-Lloyd machine involving a retention period of less than 12 min;

4) a hot carbonized product receptive to indirect reduction and rapid smelting rates involving electric furnace retention periods of 1 to 2 hr; and

5) homogeneous composition of the pellets which facilitates easier sampling and prevents segregation within the furnace.

Many interesting avenues of future development are being examined at the Dwight-Lloyd research laboratories. Some of the approaches under current development are as follows: various blends of coal and additives for improving the chemical and physical quality of carbonized pellets, preheated and reducing gases for carbonization, and coarse flux within the carbonizing bed rather than disbursed flux within the pellets.

The D-LM method of ironmaking involves the use of well-proven metallurgical equipment and opens commercial interest in regions heretofore considered marginal for conventional electric furnace smelting.

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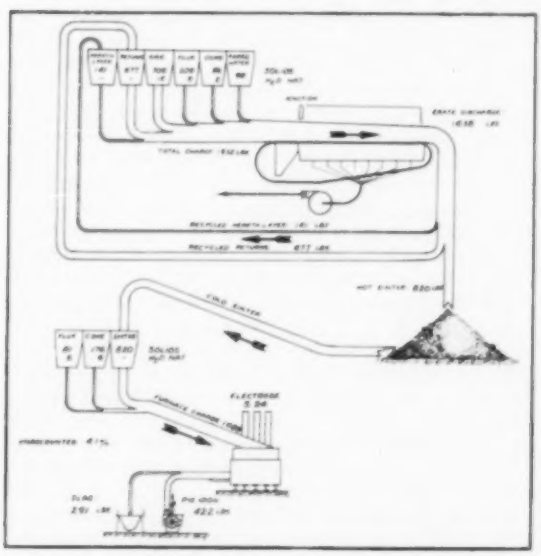


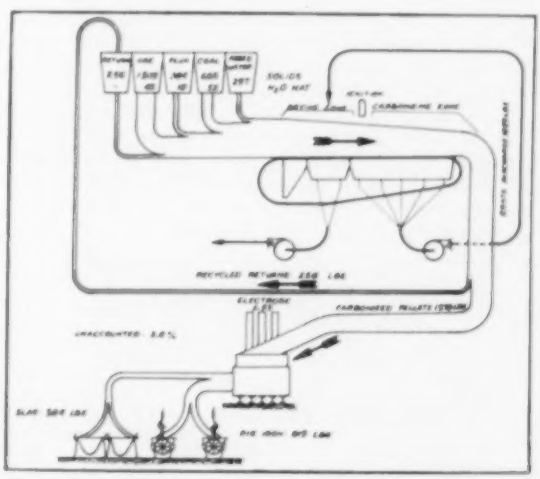


Fig. 3—Left, pilot plant materials balance for conventional electric-furnace smelting with the self-fluxing sinter coke system. Fig. 4—Above, pilot plant materials balance for Dwight-Lloyd McWane process using natural ore, coal, and limestone. Both on basis of 500 kw-hr.

# FERROALLOYS, STEELMAKING, AND THE FUTURE

*The expanding production of steels with better properties has been greatly dependent upon the development of improved ferroalloys. This paper summarizes recent developments and attempts to draw conclusions as to the future.*

by F. E. Van Voris

The partnership of alloys and steel began in 1856, when Robert Mushet added manganese to the blown metal from the newly invented bessemer-kelley process. The manganese combined with sulfur to prevent cracking during forging and rolling operations. Shortly thereafter, Bessemer discovered that silicon would prevent blowholes and make sound ingots. Carbon, which profoundly influences steel properties, was obtained from the manganese alloy or from an addition of molten pig iron. Without these three elements alloyed with iron to make steel, our industrial society would not exist. This historic technology is the basis of carbon steel production today.

The early ferroalloys were made in the blast furnace. However, there were limitations to this method, since the reduction of the oxides of silicon, chromium, and other elements required higher temperatures than the reduction of iron oxide. In the 1890's, Moissan of France and Morehead in America began experiments with the carbon reduction of ores in the submerged-arc furnace.

At the turn of the century du Chalmot produced the first electric-furnace ferrosilicon at Morehead's plant in Holcomb Rock, W. Va.[1] These high-silicon ferroalloys—75 pct ferrosilicon—aided in the development of the silicon sheet steel industry.

A modern submerged-arc furnace produces all standard ferroalloys compositions. Unfortunately, alloys so made (with the exception of ferrosilicon) are saturated with carbon which is used as the reducing agent.

Table I. Manganese Alloys
Percent Carbon & Silicon added per 0.40 Pct Manganese Addition

| Alloy | pct C | pct Si |
|---|---|---|
| Electrolytic Manganese | nil | nil |
| Std FeMn (Submerged-Arc Furnace) 0.25 pct Si | 0.035 | 0.0012 |
| Std FeMn (Blast Furnace) 0.80 pct Si | 0.035 | 0.0045 |
| Med C FeMn 1.25 pct Si | 0.007 | 0.0060 |

F. E. VAN VORIS is a metallurgical engineer, Union Carbide Metals Co. This paper was presented at a meeting of the Western Section of the National Open Hearth Steel Committee in Dec. 1959.

Low-carbon alloys originally were made by reducing ores or relatively pure oxides with aluminum —Goldschmidt or Thermit process—but utilization of this process is limited by its relatively high cost. With the availability of low-cost, carbon-free silicon produced in the submerged-arc furnace, Becket of the US in 1907 patented a more economical process. In this process ores were reduced with silicon rather than aluminum, and the high temperatures required for reaction were supplied by an open arc.

Becket later revised his process into two steps. He knew that chromium and manganese silicides made in the submerged-arc furnace directly from ores were naturally low in carbon. Thus, these low-carbon silicides were produced in the first step of his modified process, and then the silicon was removed by oxidation in an open arc. Becket's discoveries made possible low-cost, low-carbon ferrochrome—0.06 pct C—used in stainless melting, and medium-carbon ferromanganese—1.25 pct C—used in drawing-quality low-carbon sheet steels today.

The drive for even lower carbon alloys continued. Today, very low-carbon—0.02 pct C max—ferrochrome is made directly from high-carbon ferrochrome by a molten-state oxidation called the Perrin process. Even lower carbon—0.01 pct C max—ferrochrome is made from high-carbon ferrochrome by oxidizing the carbon at high temperatures under vacuum in a solid-state reaction, the Erasmus-Bagley process. These very low-carbon alloys have made possible ELC—0.03 pct C max—stainless with its superior corrosion resistance for chemical and atomic energy applications.

A further step in alloy development has been the production of high-purity electrolytic manganese and chromium. These metals are further refined when necessary by solid-state vacuum treatment to remove gases.

Aside from these improvements in ferroalloy composition, other developments have taken place. These include new packaging methods, pig casting, and exothermic alloys. The exothermic and preweighed bagged ferroalloys are now used to obtain closer control over steel analyses made in the open hearth, oxygen, and electric furnaces.

Alloy developments have had an impact on all steelmaking, from plain-carbon rimming steels to

high-alloy stainless steels. Improvements in alloy purity have aided the steelmaker who is constantly striving for improved quality, and new lower-cost alloy compositions have enabled the steelmaker to reduce his production costs. The following are examples:

## Rimming Steels

Steel for rolling into plate, sheet, and wire—a substantial part of our production—is made as rimming steel in order to obtain good surface and high mill yield. The finished product surface is largely dependent on the control of the rimming action in the ingot mold. When liquid steel contacts the cold ingot mold wall, the carbon-oxygen reaction provides a gas evolution which washes and stirs the ingot. Thus, the ingot has an almost pure iron skin which is ductile and relatively free from surface imperfections. Manganese is added to these steels in the ladle to provide good rollability and surface. Table I shows the manganese alloys listed in order of wt pct Si added for a normal manganese addition to low-carbon sheet steels—0.40 pct Mn.

It has been known that small amounts of silicon in liquid steel hinder rimming action. This is particularly noticeable in the 90-in. molds now used to provide longer slabs and coils. It is believed that the weak rimming action is caused by a lowered oxygen in the liquid steel in the mold. Fig. 1 from Hilty and Crafts[2] shows that silicon markedly lowers the oxygen content of liquid iron containing 0.40 pct Mn. Unpublished data further indicates that 0.004 pct Si almost lowers oxygen to the same level as does 0.010 pct Si shown in Fig. 1. The source of silicon recovered in the liquid steel is from the manganese addition. Table I indicates that electrolytic manganese and submerged-arc furnace manganese made under carefully-controlled conditions provide the least possible chance for silicon contamination. For higher carbon rimming steels—0.16-0.22 pct C—submerged-arc furnace ferromanganese made to max 0.25 pct Si is most desirable.

In addition to controlling silicon by careful selection of the manganese addition some steelmakers also obtain a lower steel carbon content and improved ductility in drawing quality rimming grades by using electrolytic manganese. By keeping the ladle carbon at a very low level by using electrolytic manganese, there is a tendency to counterbalance the higher segregation of carbon occurring in very large slab molds. In this case, a higher percentage of top cuts can be placed on fussy drawing-quality orders.

## Drawing Quality of Sheet

Table II shows the effect of various elements on the tensile strength, hardness, and ductility of both commercially-annealed rimmed and aluminum-killed sheet steel. From this table it can be seen that nitrogen, phosphorus, carbon, and silicon have a deleterious effect on drawing quality.

During the past year a minor portion of rimmed and a substantial portion of aluminum-killed steel has been made with electrolytic manganese to improve drawing quality. Because of the purity of the manganese addition, these heats have finished 0.01, 0.005, and 0.001 pct lower in ladle analyses for carbon, silicon, and phosphorus, respectively. As can be concluded from Table II, these steels have improved drawability. Because of the lower hardness

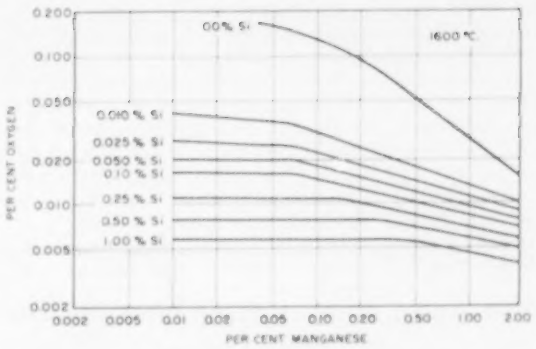



Fig. 1—Above, relationship between oxygen, manganese, and silicon in liquid iron; from Hilty and Crafts. Fig. 2—Below, silicon frequency curves for ladle deoxidation of rail steel when using packaged and loose ferrosilicon.

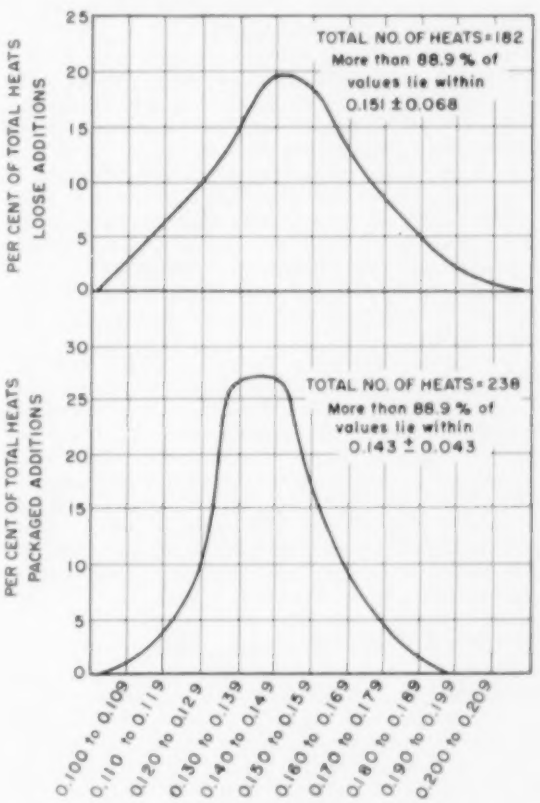



Table II. Mechanical Properties of Sheet Steels Per 0.01 Pct Wt. Increase in Concentration

| Element | Range wt pct | Increase Tensile Strength-psi | Increase In Hardness Rockwell "B" | Decrease In Uniform Elong. pct |
|---|---|---|---|---|
| N | 0.003-0.008 | 8000 | — | — |
| P | 0.00-0.15 | 700[a] | — | 0.05[b] |
| C | 0.03-0.10 | 600 | 1.50[c] | — |
| Si | 0.01-0.05 | 300 | 0.50[c] | 0.08 |

[a] Annealed at 1750°F.—0.05 pct C Iron
[b] Total Elongation
[c] Calculated from tensile strength

on heats made with electrolytic manganese, steelmakers with limited annealing capacity have been able to shorten their annealing cycle. On the other hand, steelmakers who have low residuals and conservative annealing times have not found an improvement in drawability through the use of electrolytic manganese. Claims have been made for improved surface on aluminum-killed heats made with electrolytic manganese. Heats can be tapped slightly higher in carbon and lower in oxygen content to make cleaner steel; however, improvements in surface quality are difficult to pin down.

## Non-Aging, Deep-Drawing Rimming Steel

Aluminum (4 lb per ton) is added to the ladle on some deep-drawing steel heats; its function is to tie up nitrogen, thereby preventing age hardening. The aluminum addition kills the steel and forms pipe in the ingot, thus resulting in low slab yield. It also forms aluminum oxide during teeming, which segregates at the surface of the ingot and results in poor surface on finished sheets.

Research has been devoted to the making of a non-aging, deep-drawing steel with good surface and yield. Almost 17 years ago Epstein[3] found that 0.03 pct V added to a low-carbon rimming steel attained these objectives. At that time, little was known about the annealing cycle and temperature required to make the vanadium-rimmed steel consistently non-aging by reducing the uncombined nitrogen to below 0.001 pct. Frame[4] in 1957 showed that annealing temperatures of 1300°F and soaking times of 20 hr were required. With this new information on annealing, vanadium-rimmed steel may again be tried.

Because of the early failure of the vanadium-treated rimming steel, other nitride formers have been tried. Recently combination alloys containing two or more nitride formers have been used to treat commercial heats of rimming steel. The results of this work will be inconclusive until more experience is gained. It is hoped that the complex nitride-forming alloys will permit a wider range of annealing temperatures. Should this work be successful substantial savings in sheet yield may accrue to the steelmakers.

## Semi-Killed Steels

Large tonnages of angles, beams, and plates are poured as semi-killed ingots, the structure of which assures maximum ingot to finished product yield. In spite of the ability to adjust oxygen level by the addition of aluminum to the ingot mold, close control of ladle silicon content is still necessary. The most significant development in the control of silicon level has been the use of preweighed, packaged 50 pct ferrosilicon for ladle additions. The ferrosilicon is packaged in multi-layer, moisture-proof bags, each bag containing exactly 25 lb of silicon. Ladle silicons have been held to within 0.04-0.06 pct Si on light structural and semi-killed plate grades. This improved mill yield by approx 1.50 pct. Because of improved silicon recoveries, deoxidation schedules have been cut by about 10 pct.

The frequency curves in Fig. 2 show the improvement in silicon control when packaged ferrosilicon is used for ladle deoxidation of rail steel in a tilting furnace shop on the North American continent. Other advantages have been claimed, such as lower handling losses, improved shop cleanliness and inventory control.

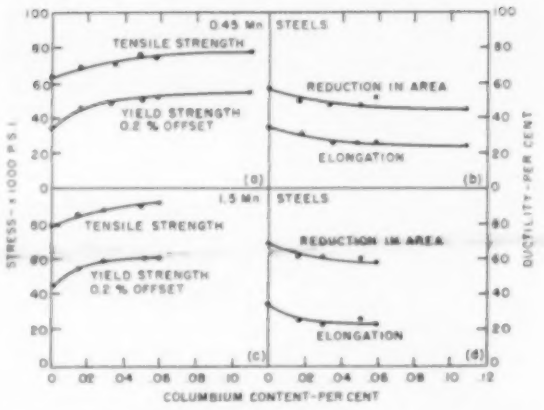



Fig. 3—Effect of columbium on tensile properties of hot-rolled carbon-manganese semi-killed laboratory steels.

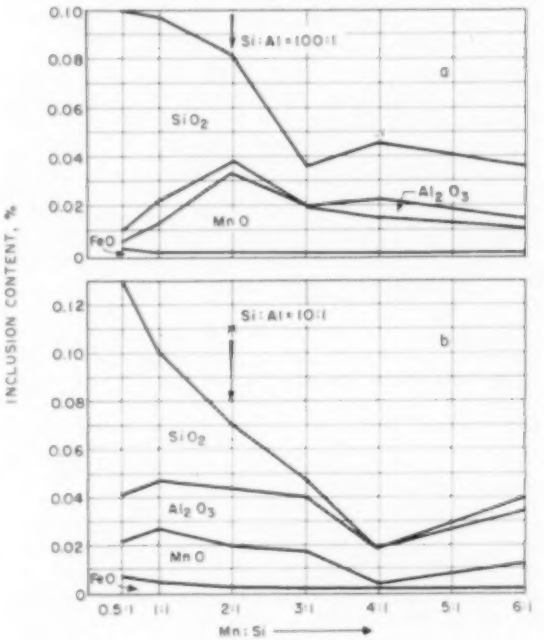
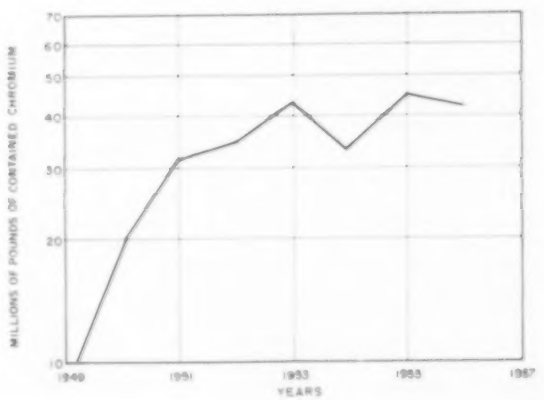



Fig. 4—Above, relationship between steel cleanliness and aluminum content of silicomanganese; after Koch and Wever. Fig. 5—Below, estimated pounds of chrome as high-carbon ferrochrome in stainless melting.



The principal problem still to be solved is the design of equipment capable of automatically adding large amounts of packaged alloys to the ladle of 400-ton open hearth heats. In spite of this problem, consumption has rapidly risen to a point where the ferroalloy industry is now packaging 12 major alloys preweighed in bags.

## Free-Machining Steel

This type of steel, once made exclusively in the bessemer converter, is now being made in the open hearth or electric furnace by the addition of sulfur, phosphorus, and/or nitrogen. Electrolytic manganese can be easily and economically nitrided, and it is now used advantageously as a combination addition of nitrogen and manganese in these bessemer-substitute steels. The advantages are 1) higher and more consistent nitrogen recovery than was previously obtainable from a chemical-compound-type addition, 2) no carbon or silicon pickup, 3) less fume, and 4) no slag in the ladle to interfere with sulfur recovery. The lower silicon content of these steels, achieved by the use of nitrided electrolytic manganese, has improved their machinability by lowering the number of silicate inclusions. Carrying this knowledge one step further, the free-machining steelmaker now purchases his ferrophosphorus to low silicon specifications.

## Columbium-Treated Carbon Steels

With the importation of foreign high-strength structural steels, competition from prestressed concrete beams, and the need for higher yield-strength line pipe, the domestic steelmaker has been hard pressed to find some economical means of raising the strength of his carbon-manganese steels without impairing weldability. It has been known for many years that columbium improves yield strength[5], but columbium at the time was under Government control as a strategic material. However, today Government restrictions have been lifted, and new large reserves of columbium ores are available. Fig. 3 shows the effect of columbium on the tensile properties of hot-rolled carbon-manganese semi-killed laboratory steels[6]. The major *kick* in yield strength occurs at a very low level columbium content—0.02 pct Cb—with some decrease in ductility. The mechanism by which columbium achieves this remarkable increase in yield strength is now being extensively studied in the laboratories of both ferroalloy producers and steelmakers.

With this discovery and the availability of more plentiful and lower cost columbium, substantial tonnages of columbium-treated carbon-manganese steels are now being made. Columbium is added to these steels as a ferrocolumbium addition to the ladle or to the ingot mold. In heavy sections, there are some problems yet to be solved in order to obtain the desired toughness.

## Killed Carbon Steels

A major contribution to the physical chemistry of steelmaking between 1926 and 1934 was achieved under the direction of C. H. Herty, Jr., sponsored by the Carnegie Institute of Technology and the Metallurgical Advisory Board. Publications, by Herty et al,[7] provided the early understanding of the deoxidation and cleanliness of killed carbon and low-alloy steels. Herty's work showed the importance of using silicomanganese rather than ferrosilicon for blocking

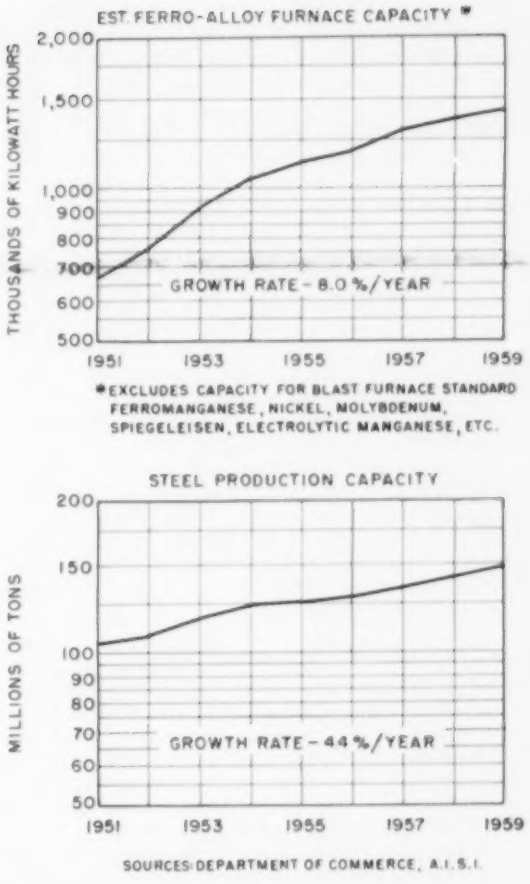



Fig. 6—Relative growth curves for the ferroalloy and steel industries.

heats. Subsequent extensive steel-plant tests show that blocking open-hearth heats with silicomanganese resulted in improved cleanliness[8]. Fig. 4, from Koch and Wever,[9] published in 1954, confirms Herty's early results. Koch and Wever indicate that low-aluminum contents in silicomanganese are desirable to further improve steel cleanliness. The principal blocking agent used today in the US is silicomanganese. This alloy is one of the high-silicon intermediate materials developed by Becket.

During World War II, the Germans, who were short of manganese, used silicomanganese alloys with a lower manganese-to-silicon ratio than those available to Herty during his original work. This low-carbon silicomanganese is included in Table III, which shows the analyses and ratios of the silicomanganese alloys now available in the US.

Low-carbon silicomanganese is now being used—with excellent results—for blocking open-hearth heats. The balance of the manganese is added to the furnace as high-carbon ferromanganese at the same time as the silicomanganese block. This practice has resulted in more uniform and higher manganese and silicon recoveries, with a consequent reduction in off-grade heats. Because of improved slag control, the blocking addition was raised from Herty's recommended 0.13 pct to 0.20 pct Si. It is thought that the heavier block may have been responsible for

improved steel cleanliness. Serious consideration is being given to the use of heavier blocks with low-carbon silicomanganese on open-hearth heats made with roof lance oxygen techniques.

## Killed Low-Alloy Steel

The teachings of Herty regarding combined silicon-manganese alloys recently have been applied in other areas, resulting in the development of high-silicon chromium alloys for use in the open-hearth furnace. The silicon content of these chromium alloys is used for the block, while the chromium provides an alloying addition. The effect of the combined silicon-chromium addition on oxygen content of the bath is not completely known. Data are lacking but assumption made from *Stainless Steel Melting Practice*, Hilty et al,[10] indicate that the combined effect of chromium and silicon may be the same as that previously shown in Fig. 1 for a manganese-silicon addition. These alloys are commonly called blocking chromes, and when compared with exothermic ferrochrome added to the ladle they result in a more economical practice. Because of the uniform recovery of chromium from these alloys, the incidence of off-grade heats has been as low as that using exothermic alloys.

## Electric Furnace Steelmaking

A principal development in electric furnace stainless steel melting has been the use of oxygen for decarburization of the melt. Prior to this, the charge was restricted to carbon steel scrap, and chromium was added as low-carbon ferrochrome during the reducing period. The use of oxygen has permitted the introduction of a low-cost, high-carbon alloy called *charge chrome* to the melt. Fig. 5 shows the extremely high growth rate of the use of high-carbon chrome in stainless melting.[11]

The limiting factor in the use of high-carbon chrome is the maximum temperature at which the furnace can safely operate during oxygen blowing. The recent introduction of a refined charge-chrome, lower in carbon and silicon, has permitted the use of even larger amounts of high-carbon chrome in the charge, resulting in further economies in stainless melting. The choice of the most economical proportion of alloys and scrap in stainless melting has been the subject of much study using linear programming methods with a high-speed computer. It is hoped that these tools will be used in other fields, for example in finding the most economical ferroalloy mix for the production of high-strength, low-alloy steels in the open hearth and oxygen furnaces.

Ferromanganese-silicon, the analysis of which is shown in Table III, has been used as a slag-reducing agent and manganese additive for electric furnace steels. This material provides a more economical source of low-carbon manganese when compared with electrolytic manganese. Some steelmakers claim that, in accordance with the teachings of Herty and others, the use of ferromanganese-silicon improves steel cleanliness. In electric furnace steel foundries, ferromanganese-silicon is used as a combined addition of manganese and silicon with a resulting improvement in cleanliness and mechanical properties of steel castings.

As mentioned earlier, the production process for the manufacture of carbon-free chromium by solid state vacuum decarburization has recently been improved. The solubility of the material so produced is now superior to that of regular low-carbon ferrochrome in stainless melting.

Table III. Analyses—Silicomanganese Alloys

| Alloy | Mn pct | Si pct | C pct | Mn/Si Ratio |
|---|---|---|---|---|
| SiMn (3.00 pct C) | 66.5 | 14.8 | 2.50 | 4.5 |
| SiMn (2.00 pct C) | 66.5 | 17.3 | 1.75 | 3.8 |
| SiMn (1.50 pct C) | 66.5 | 19.8 | 1.25 | 3.4 |
| L. C. SiMn | 51.0 | 25.5 | 0.70 | 2.0 |
| FeMnSi | 64.0 | 30.0 | 0.06 | 2.1 |

## Current Problems of the Industry

The domestic ferroalloy industry, which was started by James T. Morehead in Spray, N. C., at the turn of the century, now consists of 32 companies with an annual output valued at $500 million. Since the Korean war, for reasons of national security, the domestic industry has increased capacity to provide a stockpile of strategic material. In Fig. 6, the relative growth curves for the ferroalloy and steel industries are shown.[11] As can be seen, there is an almost 8 pct annual growth rate for ferroalloy capacity compared with a steel capacity annual growth rate of about 4.4 pct. The need for continued stockpiling of strategic material has diminshed. Thus, presently there is sufficient alloy capacity to make this industry quite competitive. This competition has resulted in many new ferroalloy compositions which have been directed toward improving steelmaking economics.

## The Future

Cooperation between the steel and ferroalloy industries in the US has been responsible for many improvements in the cleanliness, properties, and compositions of steels. Some of the more recent developments have been cited in the foregoing discussion. The threads that run through the discussion are predictions for the future. These are:

1) the development of new alloy compositions which will improve steelmaking economics;

2) the manufacture of ferroalloys to very low impurity specifications to improve steel properties;

3) that minute amounts of alloying elements will be used in the future to improve steel properties, and

4) the competitive situation in the alloy industry, will provide the spur toward higher production efficiency, lower cost, and improved ferroalloys.

Although we can no more accurately predict the future today than we could some 10 years ago, it is certain that the ever-increasing momentum of steel and alloy technologies will bring forth higher quality, stronger steels and improved metals.

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# CHINA'S MINERAL WEALTH AND METAL PRODUCTION

## *Are Communist China's boasts beginning to come true?*

by K. P. Wang

MAINLAND China has been traditionally world famous in antimony, tungsten, and tin production. In 1958 it ranked first in antimony and tungsten and second in tin. Less noticed, but already becoming prominent in the world picture—particularly with regard to markets in Sino-Soviet Bloc countries—are the metallic mineral products, such as bismuth, mercury, manganese, and molybdenite, recent outputs of which constitute between 4 and 10 pct of the world total. Several nonmetallics are also of considerable importance, with their production ranging from 8 to 20 pct of the world total; these include salt, fluorite, graphite, magnesite, and talc. In the construction, chemical, and insulating material fields, five items—cement, asbestos, mica, pyrite, and sulfur—comprise 2 to 4 pct of world total.

Probably the most outstanding developments in the metallurgical field are in the production of coal and of iron and steel. Chinese coal output is steadily rising and now ranks third in the world, constituting more than 10 pct of world production. If energy can be considered a good gauge of gross national product for a country, it is pertinent to mention that the 1959 output of coal, which is the main source of energy in mainland China, was about five times that of the pre-1949 peak year. Chinese iron and steel output also has attained noteworthy levels. Now the seventh largest world producer, Communist China may reach fifth position by 1965.

Many other mineral industries are undergoing rapid expansion, and most will become medium-size by world standards within five years. Figs. 1 and 2 indicate the relative world importance of Communist China's major metallic mineral products during 1958. The changing status of the less known Chinese mineral products are shown in Table I.

### Growth of the mineral industry

China has long been considered as having mineral resources adequate to support a moderate scale industrial program. Having an area slightly larger than that of the US, its mineral wealth can be considerable. However, the extent of resources was largely unknown until extensive geological work, coupled with vast new knowledge gained through active mineral exploitation in recent years, demonstrated that the country has a sufficiently diversified mineral base to become a first rank industrial power. With the assurance of new ore supplies, rates of extraction have been stepped up rapidly. Chinese mineral output has topped pre-Communist peak levels in almost every case. The value of overall Chinese mineral output, measured in terms of constant prices (1958), reached approximately $3 billion in 1958, or more than four times the annual maximum amount produced during the period before the year 1949 when Communist rule began. Fig. 3 shows the marked growth that took place from the pre-1949 period to 1958.

Work in the mineral field from 1949 to 1952 dealt primarily with rehabilitation and reconstruction, and output of most mineral products was brought up to past peak levels. The First Five-Year Plan (1953-57) was then launched with emphasis upon building new plants and planning for others in the future. Mineral output doubled between 1952 and 1957. Then, in 1958, came the *Great Leap Forward*, signalling the beginning of the Second Five-Year Plan. At this time, some projects started during the First Five-Year Plan period began to bear fruit.

However, the most important developments in 1958 relate to the overall economy of Communist China rather than just the mining and metallurgical industries; it was in the autumn of the year that the communes and the *mass line* were introduced. As many as 60 million people were taken off the farms to look for minerals, work in coal mines, and smelt iron. Although this program dislocated the country's economy as a whole and agriculture in particular, it served a useful purpose to the mineral industry with regard to accumulation of information on resources and in training a large number of persons in the fundamentals of mineral extraction. The by-product of this program was another great increase in mineral and metal production, coal and steel output being respectively more than 100 pct and 50 pct greater in 1958 than in 1957. The *backyard* program has since been junked, but it set the stage for growth of many small and medium semi-modern industries which are gradually taking its place. Consolidation of mining and metallurgical enterprises took place in 1959, coupled with a further moderate increase in output. Table II shows the growth of the metal industry in terms of selected products for various years.

K. P. WANG is Far East Specialist, div. of Foreign Activities, US Bureau of Mines, Washington, D. C. This paper was presented at the 1960 AIME Annual Meeting and published in Mineral Trade Notes, Special Supplement No. 59 US Dept. of the Interior, March 1960. It also appeared in Mining Engineering.

Table I. The Present and Future Status of Communist China's Less Known Minerals Products*

| | Estimated 1958 Production (Metric Tons) | Estimated 1962 Production (Metric Tons) | Present Status | Future Significance |
|---|---|---|---|---|
| **Metallic** | | | | |
| Aluminum | 27,000 | 100,000 | Deficient | Moderate |
| Cadmium | Small | Moderate | Adequate | Moderate |
| Chromite | Small, if any | Unknown | Deficient | Unknown |
| Cobalt | Small, if any | Unknown | Deficient | Unknown |
| Copper, mine | 30,000 | 120,000 | Deficient | Moderate |
| Copper, refined | 70,000 | 150,000 | Greatly deficient | Moderate |
| Copper, scrap | 100,000 | Unknown | Supplies limited | Small |
| Gold | Moderate | Moderate | Adequate | Moderate |
| Lead, mine | 47,000 | 110,000 | Small surplus | Moderate |
| Lead, refined | 60,000 | 120,000 | Slightly deficient | Moderate |
| Lead, scrap | 20,000 | Unknown | Supplies limited | Small |
| Magnesium | 1,000 | 3,000 | Adequate | Moderate |
| Nickel | Small, if any | Unknown | Deficient | Small |
| Silver | Moderate | Moderate | Adequate | Moderate |
| Zinc, mine | 45,000 | 120,000 | Small surplus | Moderate |
| Zinc, refined | 41,000 | 100,000 | Slightly deficient | Moderate |
| Minor metals | Small | Moderate | Adequate | Moderate |
| **Nonmetallic** | | | | |
| Alumina | 60,000 | 250,000 | Adequate | Moderate |
| Bauxite (diasporic) | 150,000 | 500,000 | Surplus | Great |
| Barite | 50,000 | 100,000 | Adequate | Moderate |
| Clays | Unknown | Unknown | Adequate | Moderate |
| Diamonds (industrial) | Small | Moderate | Deficient | Moderate |
| Gypsum | 400,000 | 800,000 | Adequate | Fairly great |
| Limestone | 15,000,000 | 25,000,000 | Adequate | Great |
| Phosphate rock and apatite | 300,000 | 1,000,000 | Deficient | Moderate |
| Phosphates (chemical) | 344,000 | 1,500,000 | Deficient | Moderate |
| Potassium fertilizer | Small | 200,000 | Deficient | Moderate |
| Quartz (piezo-electric) | 600 | 1,000 | Large surplus | Moderate |
| Silica (glass quality) | Unknown | Unknown | Adequate | Moderate |
| **Fuels** | | | | |
| Crude petroleum | 2,260,000 | 6-7,000,000 | Greatly deficient | Moderate |
| (Natural crude) | 1,100,000 | 5-6,000,000 | Greatly deficient | Moderate |
| (Oil from shale) | 1,100,000 | 1-2,000,000 | Could use more | Moderate |
| (Synthetic oil) | Small | Small | Could use more | Moderate |
| Refined petroleum | 2,900,000 | 6-7,000,000 | Greatly deficient | Moderate |
| Natural gas | Small | Small | Could use more | Moderate |

* Estimated by author.

China appears to be more than self-sufficient in most minerals, both for the present and for the future. However, some items are in short supply. The coal and iron ore base is very strong; coal, including coking coal, has long been considered rich, whereas iron ore has proved to be much more extensive than formerly thought. Petroleum is inadequate, but extensive exploration in recent years shows that the country will be prominent in this field, five to ten years from now. Of the ferroalloy minerals needed to support steel production, manganese, tungsten, and molybdenum are abundant, but chromium and nickel have not shown much promise. Copper, lead, and zinc reserves seem to be large enough for medium-scale operations. However, a great shortage of copper exists, and Communist China's thinking is directed towards substitution of copper by aluminum to the greatest extent feasible. Future possibilities for making aluminum and magnesium are fairly good, although not enough has been produced so far. Antimony, tin, bismuth, and mercury are of first rank, both in resources and production.

The long-term reserve position for minerals in Communist China is illustrated in Table III, and the present status of self-sufficiency for certain mineral products is evaluated in Table I.

## Regional factors

Because of China's large territory, varied geological and geographical conditions, limited transportation, and uneven population distribution, there are many regional factors affecting mineral development. Manchuria has often been referred to as the *Ruhr* of China, but its significance extends beyond the industrial aspects, since agriculture and forestry are also important there. Most of the major industrial and mineral facilities in Manchuria are concentrated in the Liaotung Peninsula, a district that has about one-third the country's industrial capacity. The relative importance of Manchuria, however, has been declining as a result of efforts by the Chinese Communists to build up the rest of the country. Neighboring North China with its vast coal and iron resources is steadily gaining in stature; an industrial belt stretching from Chin-wang-tao west through T'ang-shan, Tientsin, Peiping, Ta-t'ung, and Pao-t'ou is gradually taking shape; and Sian, in an area of rich mineral resources, is being groomed as a spring-board to development of both the Northwest and the Southwest. Central China has the Wuhan heavy industry base on the Yangtze River and the Shanghai light industry base that also has become important in iron and steel. Southeast China is the heart of the tungsten and antimony industries with a new industrial area being developed in Kwangtung Province. Southwest China has tin, copper, mercury, and some oil. The vast northwest is yielding increasing quantities of petroleum, radioactive minerals, and nonmetallics. Most regions have adequate resources of both coal and water power. The location of China's principal mineral facilities is shown in Fig. 4.

The population concentration of China is such that more than 80 pct of the people live in the eastern one-third of the country. In contrast, much of

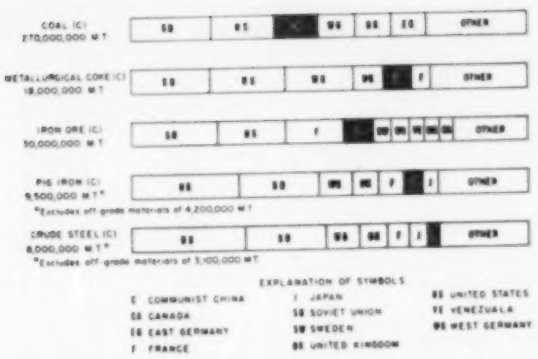



Fig. 1—World significance of Communist China's coal, iron, and steel; 1958.

Fig. 2—World significance of Communist China's ferro-alloy and nonferrous minerals. 1958.

the undeveloped mineral wealth lies in the remaining sectors of China. Thus, Communists have been trying to open up the west with a coordinated program of transport and industrial development. Some railways have been designated to tap known mineral resources, whereas others are part of the program to uncover new workable deposits. There also has been better distribution of industrial products. However, inadequate transport facilities are definitely holding back mineral development. To compensate for this, considerable emphasis has been placed upon building local industries around resources and markets—a program which has met with partial success.

## Coal

Coal is China's most valuable mineral asset, both for the present and the future. It is also its chief source of energy and metallurgical fuel. The latest Communist Chinese claim on over-all coal resources is 9.6 trillion metric tons—100 billion tons *verified*—which might be greatly exaggerated according to western standards of coal reserve classification. The important point, however, is that the coal reserve of China definitely ranks among the foremost in the world along with those of the United States and the Soviet Union. Recent exploration also has uncovered large coal beds in Central, South, Southwest, as well as Northwest China which hitherto had been considered inadequate in coal for large scale industrial development. About 30 large coal fields are said to be in existence around the country. Most of the coal is bituminous and seven of these fields have large tonnages of coking coal.

The coal industry is being rapidly expanded, output having doubled between 1957 and 1958 and risen another 25 pct betwen 1958 and 1959. The goal for 1959 production was 335 million metric tons of mine-run coal, which reportedly was more than fulfilled—347.8 million tons claimed. This constitutes 10 pct of world production. Thus, China has achieved third rank in world coal output, even when discounting a maximum of 20 pct due to losses in coal beneficiation and possible statistical exaggerations. The fact that China will soon have approximately a 100 million-ton-per-year capacity in coal cleaning facilities speaks well for technological progress in controlling coal quality. Developments in mine construction and coal extraction are equally impressive; productivity is approaching European standards and advanced techniques like cutter-loader and underground hydraulic operations are employed at all large mines.

Seven coal-mining centers—Fushun, Fuhsin, Kailan, Huainan, Hokang, Chihsi, and Tatung, in order of output—each produced more than 10 million metric tons of mine-run coal in 1959. Another 20 to 25 mining centers produced between 1 and 10 million metric tons during 1959. The rest of the output came from medium and small mines scattered around the country.

Despite the large output, there is no surplus of coal. In fact, because of distribution difficulties, shortages may exist on occasions in some areas. Most of the major coal centers are oriented towards industrial complexes, whereas medium and small mines are developed to meet local needs. Household heating is still the most important item of coal consumption. However, of the 270 million metric tons of mine-run coal reportedly produced in 1958, about 30 pct was used for iron and steel smelting, 12 pct for power purposes, 6 pct for railroad use, and 5 pct for coal mine use. Efficiency in utilization is being steadily improved. There has been a tendency to disperse coal production as much as possible to alleviate distribution bottlenecks due in part to inadequate transportation facilities.

## Iron and steel

China's iron ore base is proving to be much stronger than previously thought. The latest claim on potential reserves is a staggering 100 billion metric tons. Discounting exaggerations, the workable reserve appears to be at least 5 billion tons, more than ample to support a 50-million-ton-a-year steel industry. Ore quality and type vary greatly, but this poses no special technological difficulties. Iron ore, like coal, is widely distributed in China. While details on deposit localities are not known, the iron and steel projects now planned imply iron ore concentrations in many parts of the country. Because of limited steel production in the past, iron ore should remain much more important than scrap for steelmaking.

Now the seventh largest world producer, Communist China has an expanding iron and steel industry, already about three-fourths that of Japan and several times that of India. Construction underway in Communist China shows that an annual steel capacity in excess of 20 million metric tons is defi-

Table II. Rise in Chinese Mineral and Metal Production During 1949-59, Selected Commodities[a]

| | Pre-1949 Peak[b] | 1949 | 1952 | 1957 | 1958 | 1959 |
|---|---|---|---|---|---|---|
| Coal | 61,900 | 31,000 | 66,600 | 128,000 | 270,000 | 335,000[c] |
| Iron ore | 11,000 | 580 | 4,290 | 15,000 | 30,000 | 45,000 |
| Pig iron[d] | 2,000 | 246 | 1,928 | 5,940 | 9,500 | 15,000 |
| Crude steel[d] | 1,000 | 158 | 1,350 | 5,350 | 8,000 | 12,000[c] |
| Rolled steel | 700 | 140 | 1,100 | 4,260 | 6,000 | 8,000 |
| Crude petroleum | 320 | 120 | 440 | 1,440 | 2,260 | 3,500 |
| Cement | 2,300 | 660 | 2,860 | 5,350 | 8,000 | 12,000[c] |
| Salt | 5,100 | 2,000 | 4,950 | 8,280 | 10,400 | 13,000 |
| Chemical phosphate | 0 | 0 | small | 120 | 344 | 700 |
| Manganese ore | 80 | 1 | 191 | 700 | 850 | 1,000 |
| Tungsten concentrate | 15 | 5 | 20 | 15 | 15 | 15 |
| Antimony | 40 | 4 | 5 | 15 | 15 | 15 |
| Tin | 15 | 4 | 10 | 24 | 25 | 26 |
| Copper, refined | 3 | 2 | 10 | 50 | 70 | 80 |
| Lead, refined | 12 | 2 | 7 | 45 | 60 | 75 |
| Zinc, refined | 7 | 0 | 9 | 37 | 41 | 60 |
| Aluminum | 9 | 0 | 0 | 20 | 27 | 60 |

[a] Partly estimated by author.
[b] In most instances, the pre-1949 peak year was 1943. Major exceptions include antimony during 1916 and tin, tungsten, and manganese during the late 1930's.
[c] Represent target data. Preliminary claims for coal and crude steel output were respectively 347,800,000 and 13,350,000 metric tons.
[d] Excludes 4.2 million tons of off-grade pig iron and 3.1 million tons of off-grade steel for 1958 and an estimated 5.5 million tons of off-grade pig iron and several million tons of off-grade steel for 1959.

nitely in the making. In fact, it would not be surprising if the country should produce 30 million tons of steel by 1965 and jump to fifth place among world producers. Present iron and steel smelting practices for the larger plants compare favorably with European and Japanese standards. However, fabrication lags a little behind steelmaking and a great deal behind pig iron smelting. The Chinese have mastered the techniques of building blast furnaces, open-hearth furnaces, converters, and electric furnaces, and are reportedly starting to manufacture blooming mills and rolling mills. The great importance of large- and medium-scale iron and steel plants has been somewhat obscured by the publicity given to small plants and *backyard furnaces*. These inefficient furnaces are being abandoned, and the so-called small plants are now being operated in a fairly systematic manner.

The special characteristics of Communist China's iron and steel industry help explain why the 1958 output and the 1959 targets were revised downward in August 1959. The original output claims for 1958 were 13.69 million metric tons of pig iron and 11.08 million tons of crude steel, and the revised claims, respectively 9.5 and 8 million tons. The differences between the higher and lower figures represent the quantities of inferior products produced by the small plants and *backyard furnaces*. There is ample evidence that more than 12 million tons—1959 revised target—of good quality crude steel and 15 million tons of good quality pig iron were produced in 1959, in addition to several million tons each of off-grade products. In any evaluation of Chinese iron and steel statistics, the off-grade materials should not be ignored because they are satisfactory for making certain simple iron and steel products that do not require rigid specifications, and they also enter the resource reservoir of iron in use.

The fully integrated Anshan plant in Manchuria is still the backbone of the iron and steel industry of Communist China. Its tenth, and largest, blast furnace—about 45,000 cu ft in size with a daily capacity of approximately 2500 metric tons of pig iron—and its 23rd, 24th, and 25th open-hearth furnaces—500 to 600 tons of steel per heat—have recently gone into production. This steel complex will be expanded in the near future to about 6 million metric tons of iron and steel products yearly. In the smelting practice oxygen is now used.

Two other major iron and steel complexes to rival Anshan are in the making. The Wuhan iron and steel center in central China already has two large blast furnaces—about 40,000 cu ft in size—and three 500-ton open-hearth furnaces in operation—eight are planned. Two other blast furnaces as well as corresponding open-hearth furnaces and rolling mills, are being built or are scheduled to be built. The Pao-t'ou iron and steel center in Inner Mongolia recently blew in its first large blast furnace—same size as the Anshan No. 10 furnace—as a start to becoming one of the *big three* complexes.

Shangai has gained considerable stature as an iron and steel center in recent years; its current output of steel and steel products from a number of medium-scale plants ranks second only to Anshan. About 15 other medium scale iron and steel plants—400,000 to 1,000,000 tons per year—and 25 smaller plants are being constructed in various parts of the country.

## Ferroalloy minerals

Before the Communist era, almost all of the ferroalloy minerals produced in the country were exported. With the rapid expansion of the iron and steel industry, however, the overall picture has changed. Communist China is now making ferroalloys as well as special steels, in electric furnaces. A 1 million-ton per year manganese ore industry is being developed which would be large enough, not only to meet internal needs, but also to allow some exports e.g., Canada imported nearly 10,000 tons of manganese ore from Communist China in 1958. The Chinese apparently use much more manganese in steelmaking than western practice because of the greater availability of this material.

Chinese tungsten has long been famous in world markets; about 20,000 metric tons of 65 pct $WO_3$ concentrate is produced annually when demand is great and approximately 15,000 tons when demand is slack. Domestic consumption of tungsten concen-

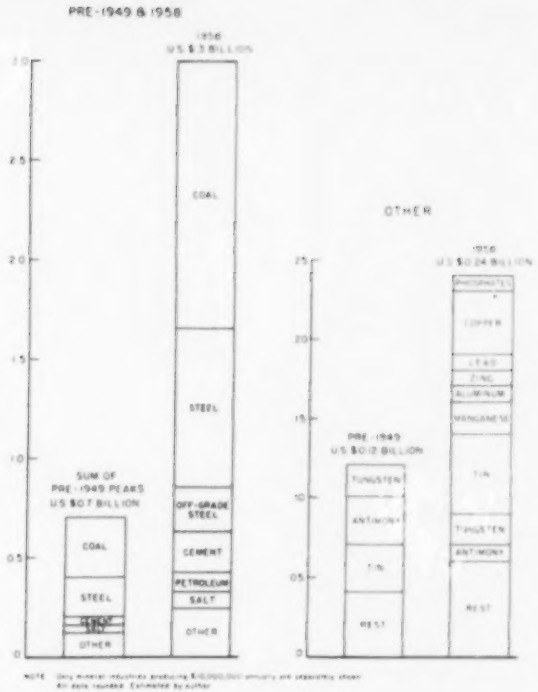



**Fig. 3—Mineral output value estimated at current prices; sum of pre-Communist peaks and 1958.**

trates may be approaching the level of 5000 tons per year to meet the rising needs for cutting tools and drill bits. Already a medium-sized world producer of molybdenum concentrates, Communist China may become even more important in the future. Present output of molybdenum is primarily exported because of the large supply of tungsten which can be substituted for many of the molybdenum applications. The Chinese now make tungsten and molybdenum metal.

There is no indication that chromium or nickel ore of any consequence is being produced, for rising demands are met by imports. Communist China appears to require about 50,000 tons of chromite —partly in the form of equivalent ferrochrome—and several thousand tons of nickel—mainly as ferronickel—annually at the present. Refractory chrome needs are being substituted to some extent by domestic magnesia-alumina materials. There is no shortage of most minor ferroalloy minerals, such as titanium and vanadium.

Knowledge of China's ferroalloy mineral reserve position is spotty. Manganese resources are extensive, probably on the order of 50 to 100 million metric tons. Most important high-grade deposits occur south of the Yangtze River, extending from Fukien Province westward through Kiangsi, Hunan, Kwangtung, Kwangsi, and Kweichow Provinces. Some important low-grade deposits also have been found in the north. Tungsten deposits are much better known; in terms of 65 pct $WO_3$ concentrate, the tungsten reserve is about 5.2 million metric tons. The four big mines—Hsi-hua-shan, Ta-chi-shan, Kwei-mei-shan, and Pan-ku-shan—in Kiangsi Province all produce wolframite. Kwang-tung Province, also a producer of wolframite, ranks next to Kiangsi. Extensive reserves of scheelite exist, primarily in Hunan Province. Molybdenum is still a big question mark, although the Chinese Communists have claimed the discovery of a very important deposit somewhere in the Chin-ling Mountains of Shensi Province. The mine that has furnished most of the country's past output is Yang-chia-chang-tzu, in Manchuria.

## Nonferrous metals

Mainland China's nonferrous metal industries (excluding light and precious metals) can be divided into two components, namely the nonferrous base metals—copper, lead, and zinc—and the nonferrous export metals—tin, antimony, mercury, bismuth, etc. The Chinese have mined and processed copper and tin by primitive methods for thousands of years and have been familiar with native lead metallurgy and mercury metallurgy for many centuries. Knowledge of antimony stemmed from the World War I period and bismuth and zinc, from the World War II period. Production of base metals has been large by world standards for several decades.

For a long time, output of *export* metals was not only far greater in value than the output of base metals but also somewhat greater in tonnage. A radical change is taking place as a result of the industrialization program now underway. Despite production increases to significant levels, deficiencies in base metals still exist, particularly in regard to copper and in general to finished nonferrous items.

Communist China will become a medium world producer of nonferrous base metals within five years. Reserves of copper, lead, and zinc have been reported at 3 to 6 million tons each, and primary output for all three metals is expected to surpass 100,000 metric tons per annum by 1962 and 150,000 tons by 1965. Most nonferrous mines and smelters have a yearly capacity of 5,000 to 20,000 tons for the metals in question, not large by world standards but fairly up-to-date. The leading base metal smelters include Shenyang or Mukden (copper, lead, and byproduct zinc) and Hu-lu-tao (zinc and byproduct lead) in Manchuria, Shui-k' ou-shan (lead and zinc) in Hunan, T'ung-kuan-shan (copper) in Anhwei, Tung-ch'uan (copper) in Yunnan, and Shanghai (scrap metals). Most mines are not far from the smelters, except for the lead-zinc mines in Sinkiang which ship their concentrates to the USSR. New nonferrous base metal centers being developed include the Chung-t'iao-shan copper mine, the Sian area copper-lead-zinc mine and smelter in Shensi, Shao-kuan copper-lead-zinc mine and smelter in Kwangtung, the T'ao-lin lead-zinc mine in Hunan, the Sidin lead-zinc mine in Kwangsi, the Hui-li zinc operation in Sikang, and an unspecified location in Lianoning. Thus, Communist China's nonferrous base metal industries are rapidly being built up from a formerly insignificant base.

Tin heads the list of nonferrous export metals. Production in recent years has been about 67 pct more than the pre-Communist peak year. Reserves can support a 30,000-ton annual output indefinitely. A yearly surplus of approximately 20,000 metric tons of refined tin will exist for some years to come, part of which will continue to be absorbed by the Soviet Union and its European satellites. The Ku-chiu—primarily lode tin—area in Yunnan is still the backbone of the Chinese tin industry; much progress has been made in expanding facilities, streamlining operations, and making better grade products. The

Table III. 1959 Mineral Reserve Position of Mainland China
(Selected Commodities)

| | First Rank | Large Reserves | Moderate Reserves | Little Known |
|---|---|---|---|---|
| **Coal, Oil, and Iron** | Coal<br>Coking Coal<br>Iron Ore | | Oil | |
| **Ferroalloy Minerals** | Tungsten<br>Molybdenum | Manganese | | Chromite<br>Molybdenum<br>Nickel |
| **Nonferrous Minerals** | Antimony<br>Tin<br>Bismuth<br>Mercury | Aluminum<br>Magnesium | Copper<br>Lead<br>Zinc<br>Gold<br>Silver | Copper<br>Lead<br>Zinc<br>Gold<br>Silver<br>Platinum |
| **Chemical Materials** | Salt | Phosphates | Pyrite<br>Sulfur<br>Potassium Ores | Pyrite<br>Sulfur |
| **Nonmetallics** | Fluorite<br>Graphite<br>Magnesite<br>Talc and Soapstone | Alum<br>Asbestos<br>Mica<br>Quartz (Piezo-electric)<br>Gypsum | Barite<br>Diamonds | Barite<br>Diamonds<br>Mica<br>Quartz (Piezo-electric) |

Fu-ho-chung—primarily placer tin—area in Kwangsi has become very important in tin production, ranking next to Ku-chiu. Fu-ho-chung tin is both extensive and clean. The Chinese antimony industry, still the largest in the world in terms of output and reserves, is not producing as much as in the past for lack of world markets. Hsi-k'uang-shan in Hunan still holds the position of the foremost antimony mine in the country. The mercury potential seems most promising, and Communist China's world position in this metal should improve in the future. Mercury deposits are wide-spread, the principal center of production at present being the T'ungjen area in Kweichow. Output of bismuth, already large by world standards, can be increased should the export market become greater. Chinese bismuth occurs with tungsten and nonferrous metals. Refined bismuth is made at several refineries, but a large part of the bismuth is exported as concentrates.

## Light, Precious, and Minor Metals

Communist China has a small integrated aluminum industry, which is in the process of rapid expansion. Annual output of primary aluminum should top 100,000 metric tons by 1962 and 150,000 tons by 1965. Rolling capacity appears to be larger than primary output at the present. Demand greatly exceeds production now, necessitating large imports of aluminum ingots. The aluminum raw material base is strong in both resources and distribution. However, much ore is not adaptable to the conventional Bayer process and other processes are being investigated with fair success. From the long range viewpoint, power and non-alumina materials for making aluminum are more than adequate. The rate of development of Communist China's aluminum industry will depend primarily on the construction of necessary facilities. The Fushun reduction plant in Manchuria and the Nan-ting alumina plant in Shantung are the most important producers at present. Two other large centers, both integrated, are being constructed at Sian in Shensi Province and Kweiyang in Kweichow Province. Communist China should emerge as a medium-sized world producer of aluminum within five years.

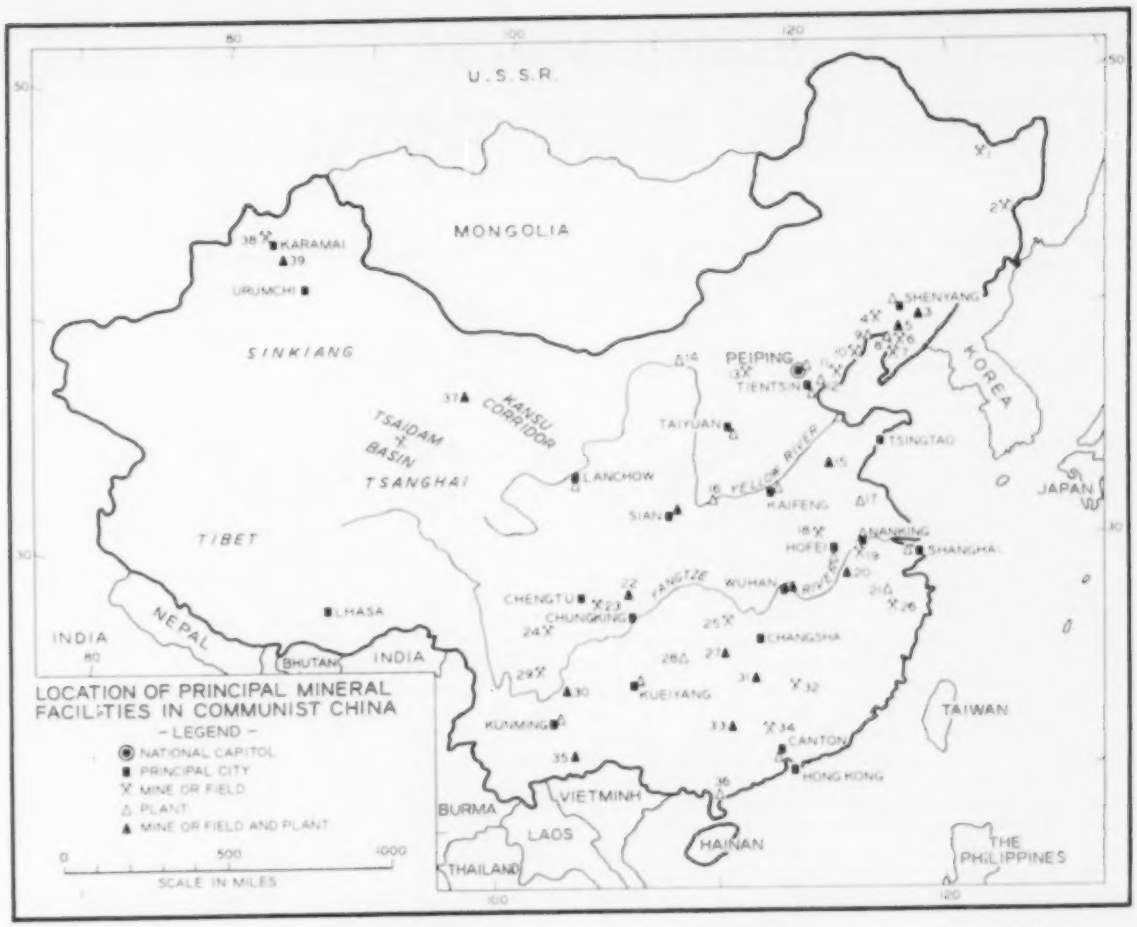
Although there is hardly any information on magnesium extraction in Communist China, small quantities are probably produced, presumably at Ying-k'ou in Liaoning Province, Manchuria. During the Japanese occupation there was a plant at this location which used sea water as well as magnesite for raw material. Magnesite resources in Manchuria are not only very extensive but of high purity. The Chinese Communists claim that they are capable of designing magnesium plants of 3000-ton-per-year capacity. Apparently, the country is somewhat deficient in magnesium at the present.

Communist China's gold resources are undetermined but believed to be extensive and widespread. Much placer gold exists, but the lode ores hold greater promise. While no statistics are available, the country probably is already a medium-sized world producer of gold. Future gold output will depend to a great extent on government policy since the tenor of Chinese ores does not seem to be particularly high. Silver is generally found and extracted with lead-zinc ores; hence production most likely is not high. There appears to be a shortage of platinum, but deposits reportedly have been discovered in Tsinghai and Shensi Provinces.

Little is known about Communist China's resources and production of radioactive and related minerals. However, three general areas have been mentioned—Sinkiang, Kwangsi, and Liaoning. At present, the only local market for radioactive material is the first atomic reactor in the country, a 100,000-kw research model completed in Peiping in June 1958. The possibilities for vanadium appear to be good, and one producer is the Chinchou or Chin Hsien plant in Manchuria which draws its ores from Luan-p'ing and Ch'eng-te districts of Jehol Province. Some selenium, cadmium, germanium, and rare earth metals have also been produced, some on an experimental scale.

## Refractories

Abundant resources of most refractories are found in the country. Chinese magnesite has long been world famous for its extensive reserves and high quality. The best magnesite deposits are located in the Hai-ch'eng—Kai-p'ing area in Liaoning Prov-




1. Hokang
2. Chihsi
3. Fushun
4. Fuhsin
5. Anshan
6. Hai-ch'eng
7. Kai-p'ing
8. Ying-k'ou
9. Hu-lu-tao
10. Yang-chia-chang-tzu
11. Katlan
12. Ch'ang-lu
13. Ta-t'ung
14. Pao-t'ou
15. Nan-ting
16. San-men Gorge
17. Chin-p'ing
18. Huainan
19. Hsiang-shan
20. T'ung-kuan-shan
21. Hsin-an Chiang
22. Nan-ch'ung
23. Tzu-liu-ching
24. Shih-mien
25. Chang-te
26. Wu-yi
27. Hsi-k'uang-shan
28. T'ung-jen
29. Hui-li
30. Tung-ch'uan
31. Shui-k'ou-shan
32. Hsi-hua-shan
33. Fu-ho-chung
34. Ying-te
35. Ku-chiu
36. Chan-chiang
37. Yumen
38. Karamai
39. Tu-shan-tzu

**Fig. 4**

ince, Manchuria. Communist China has had a surplus of calcined magnesia as well as magnesite for export. Reserves of aluminous materials suitable for making refractories are also extensive, and the Chinese Communists are making enough alumina for both aluminum reduction and refractory needs. In contrast, there is a shortage of refractory chromite. To compensate for this deficiency, a great deal of work has been done in substituting alumina for chromite in refractory bricks containing magnesia. Refractory grade silica and clay materials are also more than adequate to meet the needs of the Communist Chinese.

## Conclusions

Under the Communist regime marked industrial progress has been achieved on the China mainland. Within a decade, the country has been transformed from an economy primarily agricultural to one bristling with industrial possibilities.

During the early years of the industrialization program in Communist China, emphasis has been placed on basic goods; hence additional time will be needed to make large quantities of the more complicated products. However, regardless of the current stage of industrial development, it is apparent that the necessary forward momentum has been created. The many capital construction projects being brought into production and the additional projects being initiated confirm this observation. The accuracy of Communist China's industrial statistics can be questioned, but their order of magnitude is clear. To properly evaluate the industrial capability of the country, differentiation must be made between the absolute quantities that reflect overall strength and the per capita quantities that reflect living standards. While Communist China is well on the road to becoming a world power, its living standards will remain below European levels for many years to come.

# MATERIALS REQUIREMENTS OF HYPERSONIC FLIGHT VEHICLES

*A survey of factors that determine the materials requirements for airframe and propulsion components of hypersonic flight vehicles.*

by William S. Pellini

It is generally recognized that the future attack and defense capabilities of the Navy are greatly dependent on the utmost exploitation of missiles, rockets, supersonic aircraft, and satellite systems. The operational effectiveness of these various devices depends on a number of factors that include the specific design, the electronic components, fuels, and materials. The importance of materials to the performance, and in many cases the feasibility, of new systems has been highlighted in recent years by the realization that many design requirements could not be satisfied by available materials. This situation is not surprising because many of the present systems are based on using available materials to the limits of their capabilities; therefore, even marginal improvements in performance hinge on the results of the present day efforts of materials laboratories. Concepts and designs that call for major jumps in performance, the *quantum jump* philosophy, are repeatedly stymied by the hard fact that suitable materials may not be available for a long time. In such cases, the operational date of the system is determined entirely by the rate of effort on the materials phase of the project.

The aspects of extreme temperatures associated with the re-entry of nose cones have been publicized widely as a major problem in the area of materials. The fact that solutions have been obtained within a reasonable time for such extreme environmental conditions is often misinterpreted to signify that other, less extreme, conditions will be resolved more readily. Actually, the nose cone problem yielded to concentrated attack on a major scale and the solutions that were obtained are specific to the short-time, high heat flux environment of nose cones. This experience does not help in any way with the problem of extended exposure to moderate heat flux environments that are characteristic of various missiles and hypersonic aircraft.

The materials problems of this new era are many and diverse. The amount of effort and the probability of success cannot always be gauged in relation to the extremes of the environment and on assumptions as to the relative difficulties of coping with various environmental conditions. Examples of less glamorous, but nevertheless critical, materials problems include: corrosion resulting from reactive substances such as acids used for fuels; resistance to brittle fracture at low temperatures associated with the use of liquified gases; resistance of organic materials to ionizing radiation, ultraviolet radiation, and vacuum environments of space; and fabricability of new metals such as beryllium.

The complexity of the materials problems evolves not so much from the requirement of high performance in terms of a specific property but from requirements involving exacting combinations of properties. The desired combinations often include such *opposites* as high strength coupled with low density and high ductility. In fact, it sometimes appears that the designer simply spells out complex materials requirements in terms of what it takes to make a system operable, and then urges the materials laboratories to fill the bill. The difficulty today is that the magnitude of the effort is often grossly underestimated, leading to unrealistic planning of the lead time for the development.

Within the limitations of this brief article, it is not possible to describe in detail the materials requirements for all of the environmental conditions of flight systems. The presentation will be aimed at developing a sufficiently comprehensive spectrum of the materials requirements for the purpose of indicating the general direction and magnitude of the future research effort. In effect, the materials problems will be described in terms of the principles of flight, propulsion, and energy transfer that establish the requirements for the materials.

A broad separation of flight vehicles may be made in terms of aeronautical and astronautical systems. In conventional terms, the separation relates simply to the conditions of flight as being respectively within and outside the atmosphere of the earth. Such a separation is much too broad to provide useful definitions of the nature of flight for purposes of discussing materials requirements. As a first step, it is necessary to discuss the flight conditions of the various types of vehicles. However, before even this can be done, we must consider the nature and limits of the atmosphere of the earth.

The most striking aspect of the atmosphere is the small amount of air which is coexistent with the earth. If this total amount of the air were reduced to normal pressure and temperature, it could be contained in a band approx 5 mi thick. Actually, the density of this blanket of air falls off exponentially with increasing altitude such that 99 percent lies within 100,000 ft (20 mi). The aeronautical limits of atmospheric space, based on air breathing propulsion systems, including ram-jets, reach to about 150,000 ft (30 mi). A functional limit of flight

WILLIAM S. PELLINI is superintendent, metallurgy div., U.S. Naval Research Laboratory, Washington, D. C. This paper was presented at the 1960 AIME Annual Meeting.

by aerodynamic lift may be established at about 300,000 ft (60 mi). For altitudes in the range of 150,000 to 300,000 ft the propulsive power must be derived from rocket motors or from rocket boost, followed by glide. This zoning provides for a separation of aeronautical flight generally considered as earth bound operations, and space flight marked by satellite orbit flight or short-time ballistic and thrust flight in space.

Satellite orbit flight may be defined as operating in the gravisphere regime of the earth, i.e., in regions where the effects of the earth may be expressed in terms of its gravitational attraction. Fig. 1 illustrates this separation in terms of the distances from the earth. Compared with the earth's radius of 4000 mi, the 60 mi band of atmosphere involved in aeronautical flight and deceleration of re-entry vehicles is extremely shallow. Above 60 mi the atmosphere may be best described in terms of distances of separation between individual molecules of gas, first in terms of feet then progressively to separation distances of miles, at altitudes of 300 mi or more. In other words, the technical limit of the atmosphere (TLA) roughly marks a region of change from atmospheres involving a gas continuum to atmospheres involving free molecules of gas. Because of the residual gas present at altitudes in the order of 100 to 200 mi, satellite orbits of this altitude range are of relatively short duration. Permanent orbits require minimum altitudes in the order of 300 to 400 mi. The TLA also marks the approximate limit of aerodynamic heating (thermospheric flight) of high speed bodies by the flow of gas over the skin. Above this limit, heating of the skin may occur only by radiation from the sun.

The apparently infinite varieties of thermal flight vehicles in the news may be reduced to logical groupings codified by altitude, speed, lift, and propulsion features. These features basically determine the form, construction and the thermal environment. Fig. 2 illustrates the various possible vehicle flight paths in terms of altitude-velocity regimes available for lift, thrust, and re-entry flight. These regimes are strictly determined by nature of the earth's atmosphere and are subject to calculation, based on physical laws.

The usual starting point in a description of flight regimes is the concept of the flight corridor. The corridor describes a zone of continuous level flight with lift, commonly referred to as aerodynamic cruise. Aerodynamic cruise vehicles use wings to obtain lift; the amount of lift is defined in terms of pounds per square foot of wing surface and is a function of forward velocity of the vehicle and angle of attack of the wing with respect to the airstream. Because of the decreasing density of the air with increasing altitude, obtaining the necessary minimum value of lift requires flight at higher velocity with increasing altitude. For any given altitude, the lowest velocity of flight is determined by this aerodynamic limit and the highest velocity is established by materials limits related to the development of excessively high temperatures or pressures. In the subject figure, the materials limit is arbitrarily taken as the velocity that results in aerodynamic heating of lifting surfaces to 2000°F. The

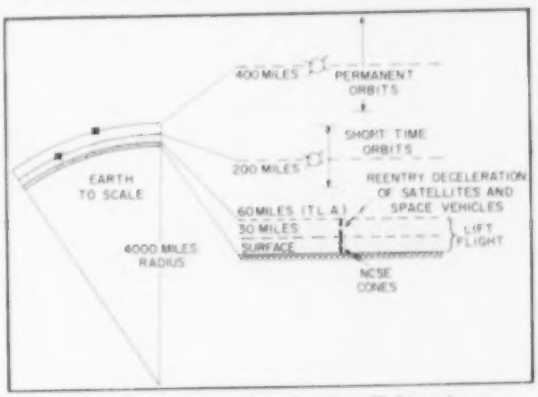



Fig. 1—Altitude separation of various flight regimes.

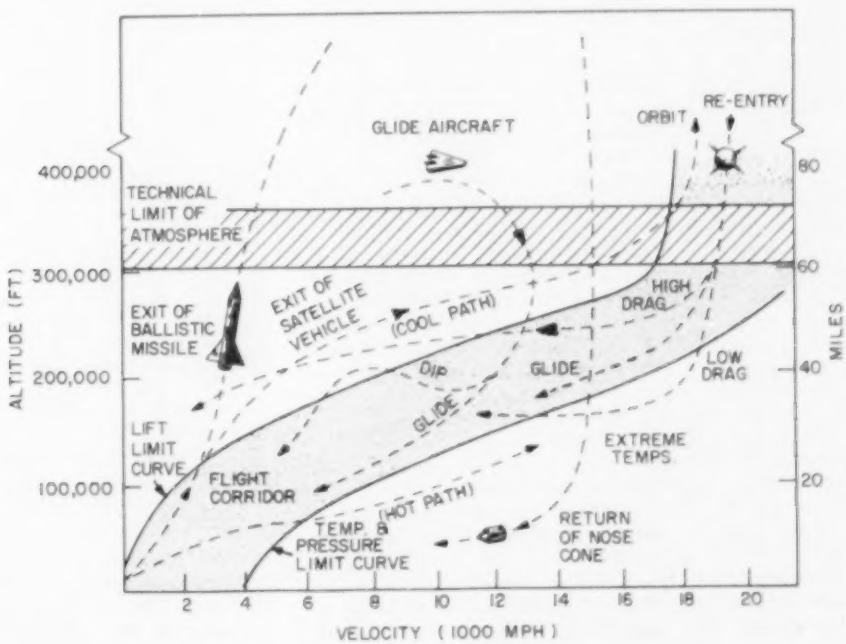



Fig. 2—Characteristic flight paths of various vehicles.

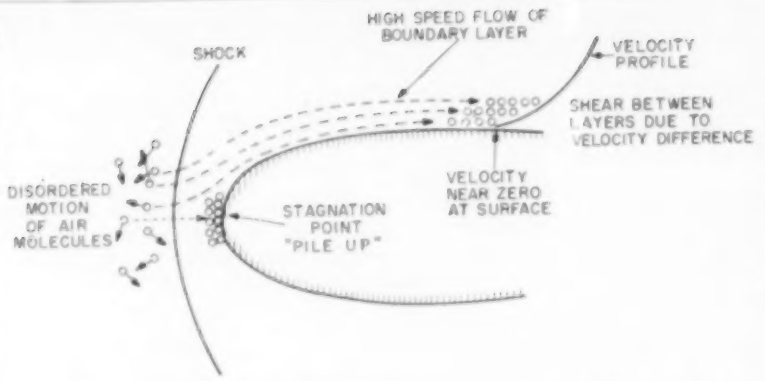

HIGH SPEED FLOW OF BOUNDARY LAYER
SHOCK
VELOCITY PROFILE
SHEAR BETWEEN LAYERS DUE TO VELOCITY DIFFERENCE
VELOCITY NEAR ZERO AT SURFACE
DISORDERED MOTION OF AIR MOLECULES
STAGNATION POINT "PILE UP"

Fig. 3—Nature of aerodynamic heating processes at stagnation points and at positions involving boundary layer flow.

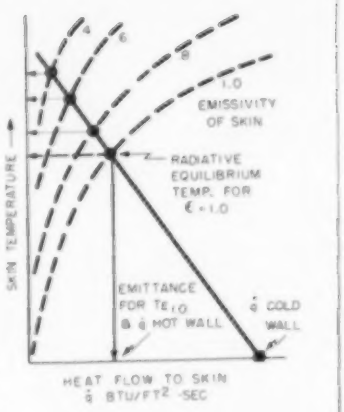

1.0 EMISSIVITY OF SKIN
RADIATIVE EQUILIBRIUM TEMP. FOR ε = 1.0
EMITTANCE FOR Te 1.0 & q̇ HOT WALL
q̇ COLD WALL
SKIN TEMPERATURE
HEAT FLOW TO SKIN q̇ BTU/FT² -SEC

Fig. 4—Relationships of radiative equilibrium temperatures to aerodynamic heat input and surface emissivity factors.

velocity that is required to establish this temperature increases with increasing altitude. For altitudes of less than 70,000 ft, excessive aerodynamic pressures are developed in the region beyond the temperature limit curve. The *open end* of the flight corridor represents the attainment of velocities required to establish orbital flight. At such velocities the body develops sufficient centrifugal force to offset the attraction of gravity, and lift is no longer required for flight.

Flight outside the corridor is primarily restricted to re-entry vehicles and boost vehicles that depend on rocket thrust for support. Boost vehicles may actually take any flight path within the diagram. Hot and cool thrust flight paths—high and low skin temperatures—are indicated for purposes of illustrating two characteristic flight programs. The hot path is not practical for satellite launching vehicles or for ballistic missile boosters, because of the very high fuel consumption rate that would be required for high-speed propulsion through the dense atmosphere and because of the high skin temperatures generated by such flight. The fuel requirement would be extreme if the flight followed a path through the region beyond that described for the *hot path*; in fact, nuclear power systems would be required to produce the necessary thrust because of the high pressures that would be generated by the airflow. Boost flight for a short time along the hot path is a requirement for anti-missiles that must reach high velocities at relatively low altitudes in order to intercept nose cone warheads.

The cool path represents a gradual increase in velocity with increasing altitude. It is the general path taken by satellite launching vehicles that must attain orbital velocities outside of the atmosphere. Fuel is conserved by such maneuvers because aerodynamic drag is kept to a minimum and heating is quite moderate. The curve that rises almost vertically and then bends downward represents the characteristic exit flight path for long-range ballistic missiles, the continuation of which is noted by the re-entry flight path of the nose cone. The boost phase of the flight terminates along the upper curved portion—outside of graph—and the flight then continues downward on a purely ballistic fall trajectory. Atmospheric drag causes a sudden deceleration of nose cones at some critical altitude, as indicated by the sharp drop to lower velocities at altitudes in the order of 50,000 ft. Extreme heating is developed during the essentially shock-like deceleration phase.

Satellite vehicle exit paths also roughly approximate the path taken by the booster for a manned glide vehicle that attains orbital velocities. Such a path is dictated by requirements for immediate transition to glide flight in case of power plant malfunction at sub-orbital velocities. If the glide vehicle is a non-orbiting, short-range glide type, such as the X-15, the exit flight path may be steeper, i.e. it may approach the ballistic missile exit path. The peak altitude portion of such a path is shown by the curve that bends over outside the TLA and then indicates a ballistic fall path towards the flight corridor. As the glide vehicle falls to altitudes within the flight corridor, the air density becomes sufficiently high to provide lift to the wing surfaces and glide flight is developed. The glide path is indicated by the curve that follows the lower limits of the flight corridor. If the vehicle carries a small rocket propulsion motor, it may first follow a glide path, then a momentary burst of power increases its altitude above that of the flight corridor. Such dips in and out of the flight corridor provide for the *cooling off* of vehicles that have limited heating capabilities, such as the X-15. In essence, if the temperatures begin to approach the capabilities of the structure, the vehicle seeks a higher altitude that results in lower temperatures for the same velocity.

Satellite re-entry of the atmosphere is indicated by the three flight paths for the return of orbiting vehicles. In order to appreciate the significance of these curves, it is essential to discuss the re-entry problem in general terms. Consider a satellite orbiting the earth at altitudes in the order of 300 mi. Such a body will have a velocity in the order of 18,000 mph. If a small retroactive rocket is fired so as to reduce this velocity slightly, the vehicle will then have less than orbital velocity and will dip into the atmosphere at a grazing angle. The high-speed airflow against the body results at first in a gradual deceleration, which is followed by a shock-like deceleration (for non-lifting, i.e. drag bodies) as atmosphere of higher density is reached at lower altitudes. The altitude of shock-like deceleration depends on the aerodynamic drag-to-weight ratio

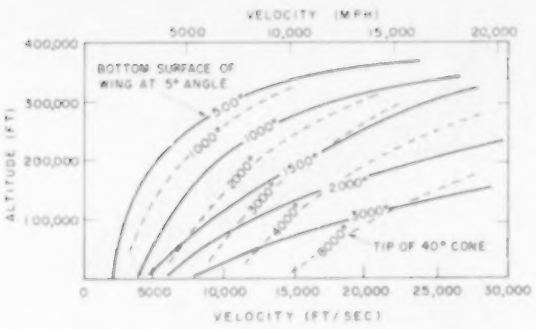



**Fig. 5—General level of radiative equilibrium temperatures for positions involving sharp nose and flat surface contours.**

of the body. As illustrated in Fig. 2, a high-density body—low drag-to-weight ratio—will penetrate to low altitudes before it suddenly decelerates to low velocities. A high drag-to-weight ratio body will decelerate at higher altitudes and with a decrease of the shock-like aspects.

Manned re-entry vehicles, based on drag flight principles, are represented by devices such as the *Mercury* capsule. This is essentially a blunt body, designed to give a relatively moderate deceleration within the 8 g limit of man's ability to absorb such forces. The feature is simplicity of construction and quick return to earth. It has little or no maneuverability and must be injected into the atmosphere with exact angle and timing, if it is to fall to a predetermined location. The re-entry flight path of such a vehicle will approximate that of a body of intermediate drag-to-weight characteristics.

The other manned type is a glide re-entry vehicle that is essentially a hypersonic aircraft. On injection into the atmosphere the vehicle may be programmed to present a high angle of attack to the airstream so as to develop a combination of high drag and high lift forces. Such a vehicle slows down gradually with a maximum of 2 g deceleration and follows a glide path within the flight corridor. After slow-down to subsonic velocities, it glides to a selected landing site.

## Aerodynamic heating

The problems that were faced in conquering the sound barrier were principally aerodynamic in nature. By developing proper designs or *form* of the aircraft and sweep-back of the wings, it was possible to alleviate a sharp rise in drag, or aerodynamic resistance, as the flight velocity approached the velocity of sound. The heat barrier cannot be circumvented in a similar manner. The heat barrier does not involve a definite limit at some flight velocity, but becomes increasingly severe with increased velocity. From a practical viewpoint the barrier may be considered to become a structural problem beyond about Mach 2.5.

A body propelled through the air displaces air particles, producing compression at leading positions, where the air is pushed out of the way. A thin boundary layer is also developed over the surfaces. The physical process of aerodynamic heating is illustrated schematically in Fig. 3. Ahead of the moving body, molecules or air exist in random motion, with a density of state determined by the altitude, a random velocity characteristic of the ambient temperature, and a pressure determined by the impulse of random collisions. The approaching body *captures* a volume of the air, compressing a portion statically against the leading position. The approach of a high-speed body with its envelope of compressed gas results in a shock-like impact on the molecules in the path of flight. The shock envelope that is developed represents the limit of the pressure disturbance surrounding the body. The compression process entails a conversion of the energy of motion into heat. The region of compressed gas that *piles up* at the leading point of the body is termed the stagnation point. Regions back from the stagnation point are subjected to high-speed flow of gas in a streamline layer, called the boundary layer. The velocity of the boundary layer decreases rapidly near the skin, approaching near-zero velocity at the skin surface. The velocity profile through the boundary layer provides for the development of shearing forces between the various levels of the boundary layer and a consequent rise in temperature of the gas. In a very crude way we may describe the heating process as due to adiabatic compression at stagnation points and due to viscosity over the regions back from the stagnation points. The important fact is that the higher the velocity and the higher the density of the gas (lower altitudes) the higher will be the temperatures of the stagnation point regions and the boundary layers. The temperatures attained by the gas envelope at stagnation point regions are much higher than for regions back from the stagnation point.

The hot gas layers transfer heat to the surface of the body by convection. The value of the heat flux is proportional to the heat transfer coefficient and the difference between the boundary layer and skin temperatures. Fig. 4 illustrates the process of aerodynamic heating. The solid line illustrates a decreasing value of the heat flux input to the skin as the skin temperature rises. The dashed lines, relating different values of surface emissivity, illustrate an increasing value of radiative heat flux as the skin temperature rises. The input heat flux and the radiative output heat flux will tend to come to a balance or equilibrium at some specific temperature level of the skin. Since the balance point represents a steady state condition—heat flux input = heat flux radiated to space—the temperature level of the skin will likewise remain fixed as long as the flight conditions remain unchanged. The temperature that is established depends on the emissivity of the surface, e.g. increasing the emissivity results in decreasing the equilibrium temperature because the surface becomes a more efficient radiator. It should be noted that the highest emissivity that a surface can have is that of a *black body*, for which E = 1.0; such a surface establishes the lowest possible radiative equilibrium skin temperature for any given condition of flight.

## Construction for steady-state aerodynamic heating

Radiative equilibrium temperatures are developed only if the flight conditions involve steady state aerodynamic cruise or long-range glide. This implies lift flight vehicles, featuring airfoils or wings for support, as contrasted with rocket thrust flight vehicles, and drag flight vehicles, such as nose cones. The latter types generally do not maintain a fixed velocity and altitude; therefore they do not attain thermal equilibrium. Because of the transient

nature of the stagnation point and boundary layer heat flux, thrust flight and drag flight vehicles may be designed on principles of absorbing the heat input rather than radiating the heat back to space. For example, nose cones may be designed on either heat sink or ablation heat absorption principles.

The general levels of radiative equilibrium temperatures that may be expected for flight at various combinations of velocities and altitudes are illustrated in Fig. 5 for a sharp nose and for a flat surface, such as the pressure side of a wing. In both cases, high values of emissivity of the skin surface were assumed. The temperatures of the sharp nose are noted to be much higher than those of the underside surface of the wing. In comparison, the temperatures for the leading edge of the wing would be higher than those of the underside surfaces, but not as high as those of the nose. It is important to recognize that the local contours determine the temperature of the gas envelope at the various positions of the body. For example, increasing the sharpness of the leading points results in developing higher temperatures for the same velocity-altitude conditions of the body. The point to be emphasized is that the local airflow and pressure conditions determine the temperature rise; therefore, it is necessary to discuss aerodynamic heating in terms of a given shape. The values cited are typical of the general temperature conditions that are involved in the design of highly-streamlined bodies representative of hypersonic aircraft and missiles.

The location of the flight corridor has been noted in Fig. 5 by the dotted area superimposed on the temperature plots. We may now consider the implications with respect to the materials of construction. The parameter yield strength divided by density provides the basis for comparison of temperature capabilities, because the determining factor is the weight efficiency of the material. If the airframe stresses are high, the high-strength aluminum alloys are useful to approx 200°F. The high weight efficiencies of the aluminum alloys may be retained by the use of high-strength steels or titanium to approx 800°F. Between 800° and 1000°F, steels may be used with somewhat lower weight efficiency. Between 1000° and 1500°F it is necessary to change to high-temperature alloys, that have relatively high density and low maximum strength; accordingly, the weight efficiency falls to low values. Above 1500°F it is necessary to use molybdenum or columbium alloys that have low weight efficiencies. For example, construction of molybdenum airframes entails a weight of approx 3-½ times that of room-temperature airframes of the same load-bearing capacity. This comparison is based on tensile stresses. If the particular construction is critical in compression and the stresses are low, it is possible to use the various metals to somewhat higher temperatures before a change to the metal of the next temperature range is required. However, if the stresses are high, the compression analysis leads to essentially the same conclusion as for the case of tensile stresses.

We may now zone the flight corridor in terms of the primary metals of construction for flight at various altitudes and velocities, Fig. 6. It is apparent that these various metals provide for the construction required for any zone of the flight corridor. However, for the high velocity regions of the corridor it is necessary to use molybdenum or columbium. The high weight penalty that is associated with such construction suggests designs other than the conventional *hot structure*, i.e. with load-bearing members subjected to the high temperatures. The alternate method entails insulating the skin from the supporting spar members and cooling to offset the leakage of heat through the insulation. Such construction is termed insulated radiative heat shield design. Fig. 7 (top) illustrates the general features of hot structure and radiative heat shield construction. It should be noted that the skin of the radiative heat shield carries no load other than the wind load and simply rests on insulation supported by the internal structure. Its primary function is one of directing the airflow and of dissipating the boundary layer heat input by outward emission to space.

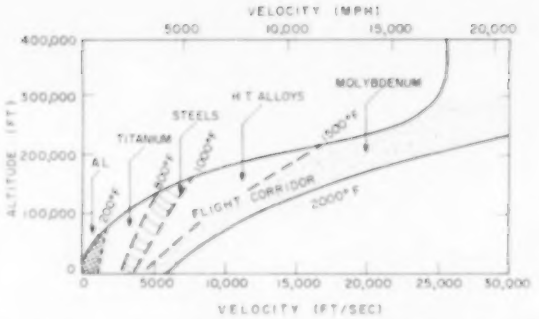



**Fig. 6—Construction required for lifting or control surfaces of cruise and glide flight vehicles; the analysis relates to highly stressed components.**

The leading edges and nose regions of hypersonic aircraft and missiles provide more formidable structural problems. Temperatures associated with velocity-altitude conditions requiring the use of molybdenum for *positions back*, may be in excess of the melting points of molybdenum for leading positions. Such positions may require the use of graphite and carbide surfaces or metallic surfaces cooled by closed system circulation of liquid metals. In the latter case the liquid metal is pumped to cooler regions that act as radiators.

## Construction for transient aerodynamic heating

The flight path of long-range ballistic missiles and lifting vehicles for satellites generally consists of a boost phase through the regions of the flight diagram above the flight corridor. Propulsion requirements related to efficient utilization of the fuel, dictate a gradual increase in velocity with increasing altitudes, thus resulting in a relatively cool path for the rocket body. Aluminum and high-strength steels generally have been used for construction of the exit vehicle. The emphasis has been on attaining the lightest possible structure because the burn-out velocities developed by the vehicle are an exponential function of the ratio of the propellent weight to the structural weight.

Re-entry of ballistic missiles and satellites poses the most extreme thermal problems. The magnitude of the problem may be assessed by the fact that a body approaching the earth's atmosphere from high altitudes possesses a large amount of kinetic energy due to its velocity. The kinetic energy of a body returning to earth with escape velocity of 37,000 ft per sec (25,000 mph) is in the order of 27,000 Btu

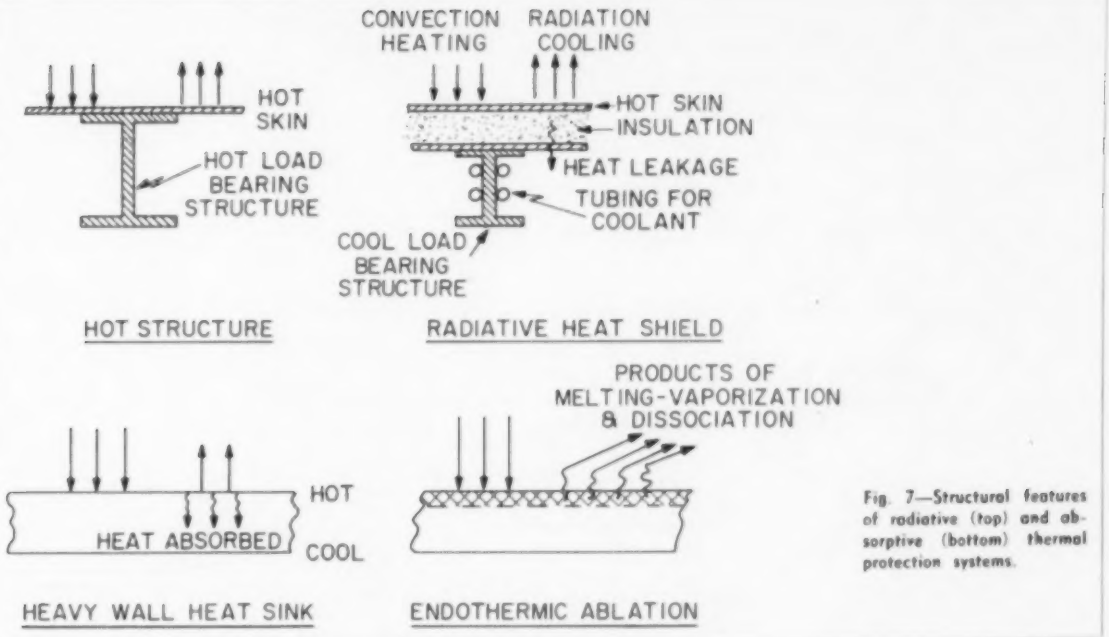



Fig. 7—Structural features of radiative (top) and absorptive (bottom) thermal protection systems.

per lb. For a ballistic missile nose cone of 23,000 ft per sec (15,500 mph) re-entry velocity, the kinetic energy is in the order of 11,000 Btu per lb, and for a 25,000 ft per sec (17,000 mph) satellite, 13,000 Btu per lb. Considering part of the total weight as a payload, the total energy is sufficient to vaporize even a thick skin composed entirely of carbon, a substance that has the highest heat of vaporization. Obviously, this event would occur only if all of the energy were transferred to the vehicle as heat. Fortunately, only part of the heat resulting from conversion of the kinetic energy must be absorbed by the vehicle. A large part of the heat may be dissipated to the air in the shock envelope that surrounds the vehicle, and the remainder may either be absorbed or radiated from hot surfaces, depending on the specific re-entry maneuver.

The actual severity of heating for re-entry is directly related to the rate of deceleration of the body as it penetrates the atmosphere. Short time decelerations signify high rates of conversion of kinetic energy to heat, i.e. intense heat *pulses* representing high heat fluxes applied for short times. Long time deceleration provides for a gradual conversion of kinetic energy to heat with a spread-out heat flux, that may be handled in large part by radiative cooling. The time periods of exposure to high heat fluxes may vary from less than 1 min for high weight, low drag, steep angle entry of long-range ballistic missiles to 10 min for low-density, high-drag spherical satellites approaching the atmosphere at a shallow angle.

The forces that act on a non-lifting—drag—body penetrating the earth's atmosphere, which increases exponentially in density with decreasing altitude, are a function of the weight-drag parameter $\frac{W\sin\theta}{C_D A}$ where W is the weight, $\theta$ the approach angle, $C_D$ the drag coefficient, and A the frontal area. High weight and steep angle imply high inertial forces, while high drag coefficients and large frontal area imply high drag forces. The interaction of these opposing forces during re-entry results in developing a point of maximum deceleration and maximum heating during the period of penetration of the atmosphere. The severity of deceleration and heating depends on the approach velocity and on the altitude at which the maximum deceleration is developed. A high-drag, lightweight body will decelerate at high altitudes under *soft* conditions of aerodynamic resistance. Conversely, a low-drag, high-weight body will decelerate at low altitudes in dense air, with *hard* conditions of aerodynamic resistance. In the former case, the deceleration may be likened to the gradual penetration of an object into loose sand, while in the latter, the deceleration may be likened to the penetration into stiff clay. The maximum deceleration load is developed at a point where the velocity is decreased to approx 0.6 of the original value. The maximum heating rate is developed at the point of 0.8 of the original velocity. This latter event occurs during the period of rapid increase in deceleration but before the peak is reached.

Inasmuch as the temperatures that may result from the high heat flux conditions of drag re-entry are above the limits of available materials, it is necessary to absorb the heat that is transferred to the vehicle. The simplest possible solution to this problem involves the use of thick skin, heat sink systems, Fig. 7 (bottom). Such systems are designed to diffuse the heat away from the surface sufficiently fast to prevent the attainment of melting temperatures during a short period of transient heating. The important property of materials for this purpose is a moderately high melting point, combined with high thermal diffusivity. The most efficient materials for heat sink applications include graphite, beryllium oxide, berylllium, molybdenum, and copper. For the least severe conditions requiring the use of a heat sink design, beryllium provides a low weight solution. However, this material is noted for its toxicity and lack of ductility. For more severe conditions, graphite and beryllium oxide provide low-weight solutions. The problems of using such

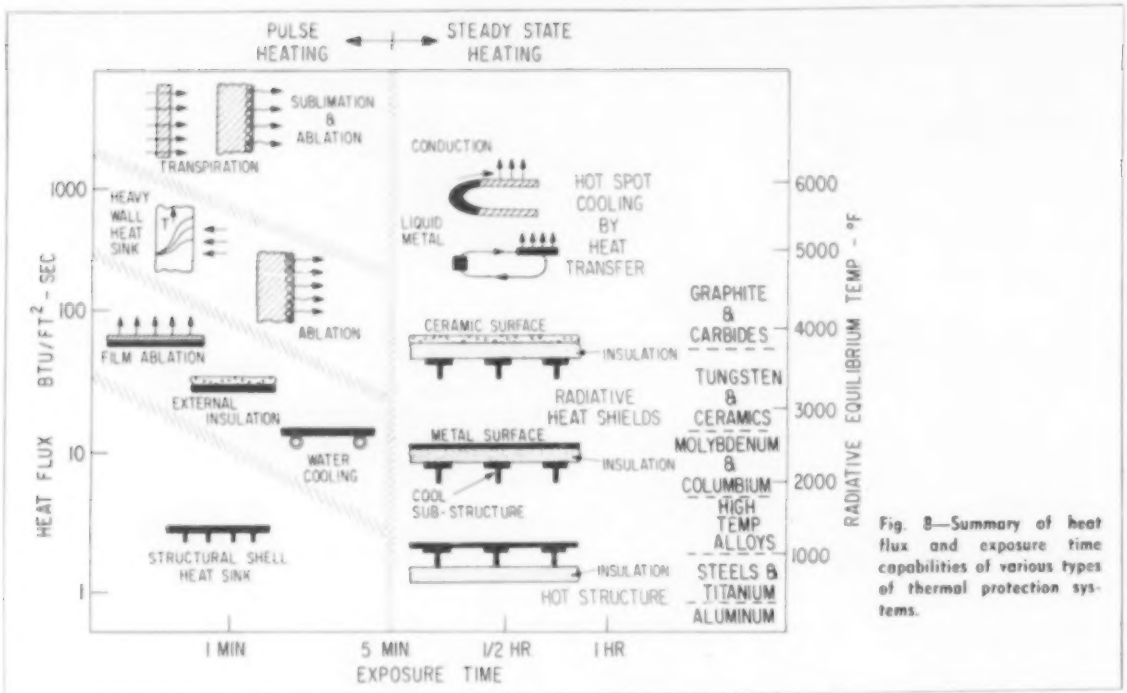



Fig. 8—Summary of heat flux and exposure time capabilities of various types of thermal protection systems.

highly brittle materials presently restrict their applications. Molybdenum approaches the performance of graphite, but at a severe weight disadvantage. The manufacture of this material into a suitable structure would present difficulties, however, its ductility exceeds that of beryllium by a large degree. Copper provides for intermediate heat-absorbing capabilities but at the cost of a large weight penalty. This relatively cheap, highly ductile metal provides the only apparent solution which does not involve severe manufacturing, storage, and use problems.

Another method of heat absorption that could be considered, involves ablation—melting or vaporization—of materials with high heats of fusion or sublimation, Fig. 7 (bottom). Ceramics and organic materials are much superior to metals in the general process of ablation. Here, the design problem involves the development of combinations having optimum-performance characteristics for specific levels of heat fluxes. Carbon is unique in that it may be used both as a heat sink and as an ablation—sublimation—material. Transpiration cooling involving porous nose cones, that are cooled by the passage of gases or liquids through the pores, may be considered. Such methods generally involve pumping and control systems of undesirable complexity for re-entry bodies.

## Relative capabilities of thermal protection systems

A simplified summary of the aerodynamic input heat flux capabilities of the various basic types of thermal protection systems is presented in Fig. 8. A broad separation is made between heating conditions involving short time exposures—pulse heating—and conditions involving steady-state heating. Detailed studies of the thermal exposure conditions of a wide range of thermospheric flight vehicles, suggests a practical separation of pulse and steady-state exposures in the range of 3 to 5 min. For exposure times of less than 3 min, the heating cycle ordinarily involves a bell-shaped, heat flux pulse. For exposures in excess of 5 min a square wave, heat-flux cycle generally is to be expected.

Pulse heating conditions may involve heat flux inputs that would result in exceeding the melting point capabilities of any material of construction, if temperature rise is permitted. There is no question regarding the necessity of using absorptive systems of high heat capacity for such conditions. This environmental zone is denoted in the figure by the sketches representing transpiration, sublimation, and ablation thermal protection systems. The corresponding heat fluxes may range from 500 to 10,000 Btu per sq ft per sec.

Pulse heating conditions, involving heat fluxes in the range of 50 to approx 500 Btu per sq ft per sec, require the application of heavy-wall heat sink systems. For heat fluxes of less than 50 Btu per sq ft per sec, the shell of the vehicle—missile body, for example—may provide the required thermal capacity, if the exposure time is less than 1 min. For exposures of several minutes, it is necessary to augment the thermal capacity of the shell by the use of one of the following devices:

a) water cooling—tubing, spray, soaked mat, etc.
b) transient external insulation (transulation), or
c) ablation of inorganic films, such as teflon.

These comparisons consider both weight and heat flux capabilities. In fact, the reason for eliminating the use of absorptive systems beyond an exposure time of approx 5 min is the very great weight of the absorptive material that is required. For long-time exposures it is necessary to radiate a large amount of the convective heat input in order to provide reasonable design weights. This fact is immediately apparent on considering that the heat load for exposure times in the order of ½ hr may total ½ to 1 million Btu per sq ft for leading edges of hypersonic glide vehicles. An absorbing material that has the relatively high heat absorption efficiency of 2000 Btu per lb would require a weight of 250 to 500 lb

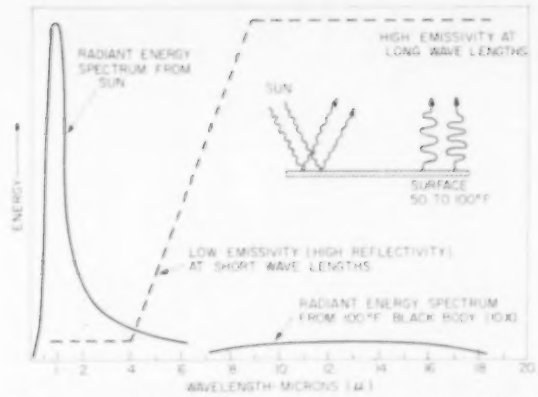

RADIANT ENERGY SPECTRUM FROM SUN
HIGH EMISSIVITY AT LONG WAVE LENGTHS
SUN
SURFACE 50 TO 100°F
ENERGY
LOW EMISSIVITY (HIGH REFLECTIVITY) AT SHORT WAVE LENGTHS
RADIANT ENERGY SPECTRUM FROM 100°F BLACK BODY (10X)
1 2 4 6 8 10 12 14 16 18 20
WAVELENGTH MICRONS (μ)

**Fig. 9—Energy balance involving absorption of short wave radiation from the sun and emittance of infrared radiation from skin determines the temperature of satellite bodies. The dashed curve represents the surface optical characteristics required for developing desired surface temperatures.**

per sq ft to accomplish this function. Radiative systems may be designed to radiate back as much as 95 pct of the aerodynamic heat input; thus, the absorptive capacity—for heat leakage—that is required may be reduced to reasonable values.

Various types of radiative systems are illustrated in the long-time exposure region of the diagram. For long exposures the proper reference for the environmental conditions is the radiative equilibrium temperature that is established by the aerodynamic heat-flux input. As the radiative equilibrium temperature is increased, it is necessary to use a range of materials of increasing temperature capability, as noted by the temperature levels referenced to aluminum, titanium, high-strength steels, high-temperature alloys, columbium, molybdenum, ceramics, tungsten, and graphite. It is noted also that the construction should normally change from hot structure designs to insulated radiative heat shields involving refractory metal surfaces, then finally to ceramic surfaces as radiative shields. At the highest levels of heat fluxes it may be necessary to remove a portion of the heat by conduction—transfer back—or by the use of pumped, liquid metal, closed cycle systems.

The thermal environment experienced by various types of thermospheric flight vehicles may now be related to the thermal protection system zones designated in Fig. 8, as follows:

**Shell Heat Sink Zone;** Satellite launch rockets; IRBM and ICBM rockets, and short range missiles.

**Shell Augmentation Zone:** Body of anti-missile on exit; long-range missiles; drag re-entry of low-density satellites; and short-range, glide-flight vehicles.

**Heavy Wall Heat Sink Zone:** Short- and intermediate-range nose cones; manned re-entry capsules; satellite dump; nose of anti-missile on exit; and nose regions of future hypersonic missiles.

**Transpiration, Ablation, Sublimation Zone:** Nose cones of high ground-approach velocity (low drag).

**Radiative Systems (500° to 1000°F):** Mach 3 aircraft and long-range supersonic ramjets.

**Radiative Systems (1000° to 2000°F):** Mach 4 to 6 hydrogen and nuclear ramjets; and glide vehicles of short and intermediate range (X-15 types).

**Radiative Systems (2000° to 5000°F):** Hypersonic glide re-entry vehicles; sub-orbital glide attack vehicles and missiles; lift re-entry capsules; and low-level, Mach 5 to 6, nuclear ramjets.

For the radiative systems, the high end of the temperature range relates to leading edges and nose stagnation points and the lower end of the range to positions back.

In discussions to follow, on thermal protection requirements of solid-propellant rocket nozzles, reference will be made of heat-sink solutions for first-generation systems. The heat-flux conditions of the nozzle throats are in the order of 100 to 500 Btu per sq ft per sec and the exposures may range from 0.7 to 1.2 min. The analyses presented in Fig. 8 indicate that heat sink systems may logically be used for such conditions.

## Temperature control of satellites

Because of the essential lack of atmosphere at orbiting altitudes, the heat transfer problems of satellite bodies are considerably different from those described for vehicles operating within the atmosphere. Free molecules that exist at altitudes of 100 mi or higher, do not develop convective heating. Thus, the only significant heat-transfer process involves radiation heating of the skin caused by solar flux or cooling due to radiation to space. The thermal problem in this case does not primarily involve the structure of the satellite, but rather the delicate electronic equipment comprising the payload. For this reason the concern is with relatively small temperature changes.

The factors involved in the temperature control of satellites are illustrated in Fig. 9. The spectral distribution of the solar flux is concentrated at short wave lengths in the range of 0.3 to 2$\mu$. This distribution is determined by the high temperature of this source. The integrated value of the flux is in the order 0.12 Btu per sq ft per sec near the earth. The emission spectral distribution of a surface operating at near ambient temperatures, say 100°F, is spread out over a range of long—infrared—wave lengths in the range of 8 to 20$\mu$. The intensity of the emission of such a low-temperature body is relatively low. In Fig. 9 the scale for the low-temperature spectrum is represented at 10 X scale compared with that of the sun energy spectrum. Obviously, low-temperature bodies are poor emitters; thus, if a large temperature rise is to be prevented, it is necessary to adjust the optical properties of the satellite surface so as to provide for low absorptivity at short wave lengths and high emissivity at long wave lengths. The dashed curve illustrates the ideal optical features of such a surface.

The exact value of the ratio of solar absorptivity $a$ to infrared—low temperature—emissivity $E$ determines the equilibrium temperature attained, as illustrated in Fig. 10. Ratios in the order of 0.1, as provided by a white painted surface, result in undesirably low temperatures. The high ratios provided by polished metal surfaces result in excessively high temperatures. Black, or oxidized gray surfaces provide for ratios close to one which are necessary for maintaining temperatures close to the normal ambient range. Actually, complications due to shape and orientation with respect to the sun dictate the use of striped or polka-dot patterns, illustrated in the figure. The relative area and distribution of such *light* and *dark* regions provide for developing of the desired temperature.

If very exact temperature control is required, it may be necessary to use active control systems.

Such systems involve fan-like, shutter arrangements that open or close to present a dark or light surface in response to a temperature sensing device.

The Vanguard satellites had unique requirements involving high visibility from optical, ground tracking stations. This requirement for a shiny surface —high reflectivity—would have resulted in a very hot satellite. The solution in this case was to apply a thin film of silicon monoxide over a polished aluminum surface. Silicon monoxide is transparent to short wave lengths and is a highly efficient emitter at long wave lengths. Thus, a large fraction of the solar spectrum in the visible range—0.3 to 0.7$\mu$—was reflected by the polished aluminum surface, transmitting through the transparent oxide surface. In turn, reasonably low temperatures were maintained by infrared emission from the silicon monoxide surface.

A satellite that revolves about the earth passes from the sunlight into the earth's shadow and back into the sunlight in periodic fashion. Such transients, or periods of 40 and 60 min for shadow and sunlight respectively, in the case of a near earth orbit, pose special problems of temperature control for passive systems. Compared to the face exposed to the sun, the earth-side face undergoes less drastic changes in temperature because it always sees a relatively warm earth. Spinning of satellite bodies serves to alleviate this problem; however, certain types of observation or communication satellites must maintain a fixed orientation to the earth that prevents the use of this technique. A full discussion of the temperature-control problem for all cases is outside the scope of this presentation. It should be obvious, however, that the problem of choice of materials for thermal control in space is primarily a question of optical properties of surfaces rather than of strength. Restrictions on weight dictate the use of light metals with special surface treatments.

The surface treatment problem is additionally complicated by the high vacuum and ultraviolet environment of space, that is destructive to organic materials such as the vehicles of paints used for striping. The effects of meteoric particles that may puncture the shell, and of high-energy charged particles that may sputter and erode the surfaces, are as yet poorly understood.

## Rocket propulsion requirements

Rocket motors may be designed for the use of either liquid or solid propellants. The liquid type consists of: 1) a combustion chamber, designed for the mixing and burning of the fuel and oxidizer; 2) separate tanks for storing the two liquids; and 3) either fast-acting pumps or a gas pressure tank to provide for high-pressure delivery of the liquids to the combustion chamber. The solid-type consists of a nozzle to direct the jet gases and a pressure vessel that contains the solid propellant and the high-pressure gases developed during the combustion. Both types require directional control systems entailing either jet deflector vanes or a gimbal mount for the nozzle.

The index of merit for a rocket motor is the specific impulse value ($I_s$) that is determined primarily by the combination of oxidizer and fuel used for the propellant. The $I_s$ value relates to the pounds of thrust produced per pound per second of propellant consumed. The attainment of high specific impulse requires propellant combinations that produce the highest possible jet velocity. In turn, this requires maximizing the combustion temperature and minimizing the molecular weight of the combustion products. These relationships may be expressed as follows:

$$I_s = \frac{\text{lb (thrust)}}{\text{lb/sec (propellant consumption)}}$$

$$I_s = k\, V_{jet}$$

$$V_{jet} = k\, \frac{(\text{gas temp})^{1/2}}{(\text{gas mol wt})^{1/2}}$$

The highest values of $I_s$ for chemical combustion are obtained by the use of hydrogen in combination with oxygen (LOX) or fluorine. The $I_s$ values for these exotic fuels are in the range of 375 to 400 as compared with 250 to 275 for conventional fuels such as LOX and hydrazine. To attain higher $I_s$ values it is necessary to use nuclear rockets, consisting of an assembly of hot fuel elements over which is passed a low molecular-weight gas, such as hydrogen. The hot stream is then expanded through a nozzle to provide the thrust. Hydrogen, heated by fuel elements operating at approx 5000°F, the highest feasible temperature of operation, may provide $I_s$ values in the order of 1200. In other words, such a nuclear rocket may provide three times the thrust per pound of propellant that is theoretically possible for chemical rockets and four times that of present-day chemical rockets. The importance of $I_s$, as related to payload and to final velocities attainable by rockets for satellite boost, is discussed in relation to construction features.

Cooling of liquid motor systems is generally accomplished by regenerative methods, as illustrated in Fig. 11. Basically, this involves passing the fuel or oxidizer through a double wall or tubing structure surrounding the chamber, prior to exit into the chamber. Such methods are possible because of the large volume of fuel that is burned in a relatively short time. High temperature gradients are developed between the flame wall and the coolant passage wall, as illustrated. The double-wall construction often poses complicated hydraulic problems, involving channeling of the flow, with the result that, in some regions, the liquid may overheat and produce boiling. This event results in a reduction of heat transfer rates and immediate heating of the wall to melting. It is possible to construct such motors with aluminum, at least for the cases involving lower flame temperatures. For high flame temperatures and high pressures, stainless steel is adequate, if high flow rates are maintained. While design may be critical for such motors, particularly in the throat region, there does not appear to be basic materials limitations due to temperature. Difficulties may arise, however, from corrosive attack, particularly for exotic combinations of oxidizers and fuels, such as fluorine.

The combustion temperatures of solid propellant fuels are in the range of 4500° to 6500°F. Two general types of grains are used: a solid grain that burns progressively from one end—cigarette burning—and a scalloped, perforated grain that burns from the center radially to the circumference—star grain. The nozzle throat for solid propellant motors provides severe thermal problems and, additionally, is subject to enlargement by abrasion due to the high velocity exit of solid combustion products. Such enlargement is undesirable because it changes the thrust of the motor during flight.

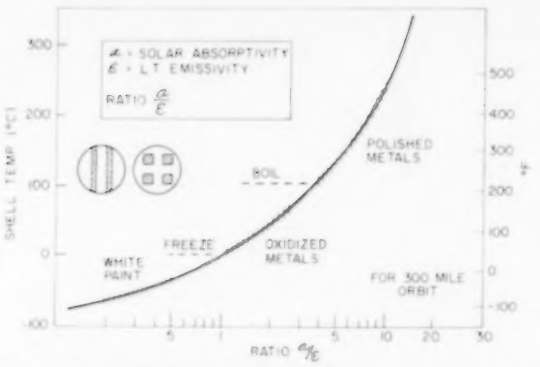



Fig. 10—Temperatures developed by surfaces of various $\alpha/\epsilon$ ratios.

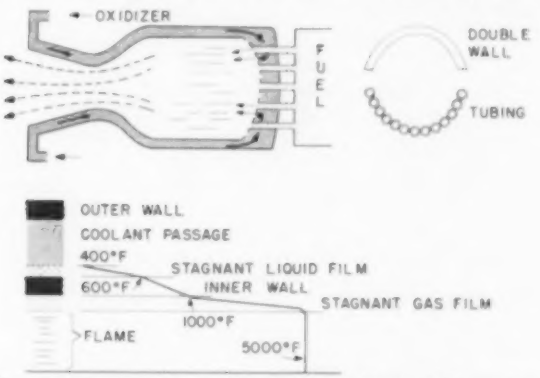



Fig. 11—Regenerative cooling features of liquid propellant nozzles.

Fig. 12 illustrates six basic types of solid propellant rocket nozzles. The simplest design (type 1) suitable for short burning times in the order of 3 to 6 sec, consists of a thin steel wall. By coating with ceramics, such as flame-sprayed alumina or zirconia (type 2), a thermal lag is developed that may potentially double the allowable burning time. Designs, suitable for burning periods ranging from 20 sec to approx 1 min (types 3 and 4), require the use of refractory materials and steel as combination heat sinks. The simplest designs utilize conventional graphite and are particularly useful for propellants having flame temperatures not exceeding approx 5000°F. As the flame temperatures are raised to 5500°F, the use of conventional graphite becomes marginal, restricting the time of operation and necessitating a change to molybdenum or in special cases to tungsten. Such composite nozzles are very heavy, because the large amount of heat that must be absorbed by the wall in order to prevent melting, requires a high heat-sink capacity system. This capacity is obtained by the use of walls of 1 to 2-in. thickness. The long burning times of such rockets also requires the use of thermal protection for the base of the chamber. Plastic insulation in the form of phenolic fiberglass laminates provides a simple and effective solution to this problem.

Burning times extending to several minutes are possible only for high-altitude rockets, such as the final stages of satellite launching vehicles. Such rockets operate at very low chamber pressures because of the low back pressures. Burning rates are designed to be very low, and the thrust time accordingly can be extended to possibly as high as 3 to 4 min. The use of heat sink solutions for firing periods of this duration is prohibitive because of stringent weight limitations for final stages. The only practical designs (types 5 and 6) would seem to require the use of radiative cooling principles, involving ceramic or refractory metal construction. Such nozzles may be relatively thin-walled because of the low back pressures required at very high altitudes.

Procedures for varying the direction of thrust in solid-propellant motors generally depend on a deflector device, such as vanes in the center or sides of the jet stream; obviously, this is a most demanding service for materials. Consideration of the temperatures involved, suggests the use of graphite for low flame temperatures and short firing times, and either molybdenum or tungsten for more severe conditions of temperature and time.

All of the large, first-generation, satellite boosters are based, at least for the first stage, on liquid propellant rocket motors. In view of the complexity of such systems, and the reported high reliability of solid-propellant motors, one may wonder why the solid propellant rockets were not used initially. While solid propellant rockets have distinct advantages of simplicity, they also have distinct disadvantages. The payload capabilities of solid propellant rockets has been inferior to that of the liquid types because of lower $I_s$ and higher metal parts weight. Another drawback is the difficulty of varying the thrust.

## Mass ratio factors

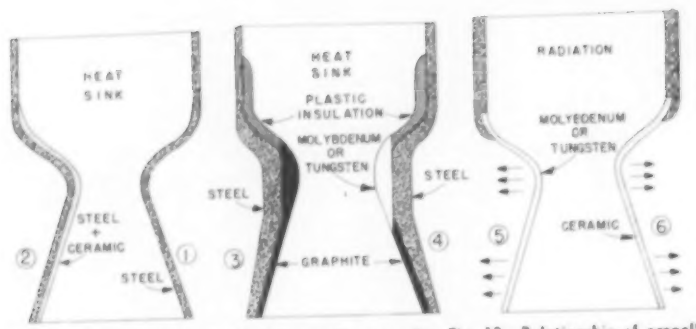
The final velocity attained by a satellite or escape vehicle depends on the $I_s$ of the rocket motor and the ratio of takeoff weight ($W_i$) and *all up* or final weight at burn-out ($W_f$).

$$V_{\text{Burn-out}} = I_s\, g \ln \left( \frac{W_i}{W_f} \right) *$$

* Mass ratio.

The relationships of these factors is illustrated in Fig. 13. For simplicity of presentation, the mass ratio is expressed in terms of the propellant fraction, i.e. the fraction of the rocket weight represented by the propellant. The remainder is the sum of the weights of the inert parts of the rocket and of the payload. The structural significance of the propellant fraction term may be better appreciated by comparison to content fractions of common packaged items. By such comparisons, conventional construction may be described as a proportion of inert components weight to propellant weight which is equivalent to that of the can to the contents of canned foods. The proportions for advanced construction compares to the relationship of the eggshell weight to the content weight. The attainment of such extreme construction efficiency presents serious problems in fabrication and in selection of materials.

The relationships presented in Fig. 13 indicate that, with *conventional* construction, the final velocity attained (for a single-stage rocket) is in the order of 1.5 times the jet velocity. For highly-advanced rockets, having propellant fractions of 0.90 —mass ratio 10—it is possible to attain final velocities in the order of 2.25 times the jet velocity. It may be noted that, for conventional fuels, a single-stage rocket of conventional construction—0.85 propellant fraction— attains a burn-out velocity in the order of 8500 mph. By using the most efficient propellant combination ($H_2$—$F_2$) and a 0.90 propellant fraction construction, it is barely possible to attain



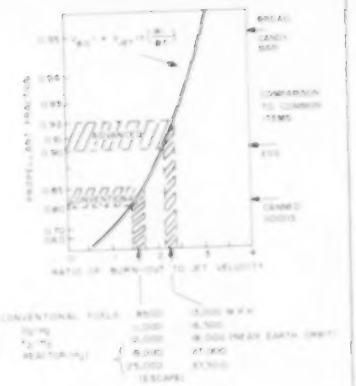



Fig. 12—Construction features of solid propellant nozzles. Fig. 13—Relationship of propellant fraction to the relative burn-out velocity of single stage rockets. The burn-out velocity also depends on the jet velocity of the particular propellant, as indicated.

earth orbit velocities—18,000 mph—with a single stage. Single-stage nuclear rockets may provide for either earth-orbit or escape velocities—25,000 mph—with conventional construction, depending on the operating temperature of the reactor.

In order to attain high velocities with conventional propellants and conventional construction, it is necessary to use staged vehicles. By using several stages, it is possible to attain a final velocity in direct proportion to the number of stages. In other words, for equivalent construction and the same $I_s$—same propellant—for each stage, a third stage would have a final velocity three times that of a single stage. Thus, three stages of conventional fuel and conventional construction rockets are required to attain escape velocity for the final stage. The same performance may be obtained by a two-stage rocket featuring conventional fuels and advanced construction. These comparisons relate to essentially zero payload weights; as payload is added, the final velocities that are attained are greatly decreased, requiring the use of additional stages. The penalty for obtaining earth orbit or escape velocities by staging of inefficient rockets is that the payload becomes very small, because each stage, in turn, becomes the payload of the previous stage. Thus, for a 0.90 propellant fraction, three-stage system, the final weight that is accelerated to escape velocity becomes 1/10 x 1/10 x 1/10 or 1/1000 of the takeoff weight.

A single-stage nuclear rocket may be expected to place *all up* weights in earth orbit or escape, of 10 to 40 pct of the take-off weight, depending on the operating temperature of the reactor. Fig. 14 illustrates the approximate relationship of *all up* weight in earth orbit, to propellant weight, for $I_s$ values ranging from those of conventional fuels to those of hydrogen propellant, hot wall reactors. If 4000°F is taken as a practical limit for operation of hot wall reactors, it may be deduced that a 40 pct payload and structure weight may be placed in earth orbit by a single stage, as compared with 1 to 2 pct for a two-stage rocket of advanced construction, using advanced types of conventional fuels ($I_s$ = 250 to 275). A single stage, exotic fuel rocket is represented as delivering approximately 10 pct structure and payload in orbit. These comparisons highlight the importance of nuclear rockets for purposes of placing large payloads in earth orbit. The feasibility of such systems depends on the development of moderator and fuel element materials that would permit reliable construction of approx 4000°F hot wall reactors. In order to attain such temperatures it is necessary to use graphite or carbide moderator materials and uranium carbide fuels. The principal problems involve the reliability and stability of these materials under conditions of severe thermal stresses and in an environment of hydrogen.

## Rocket motor casing construction

The importance of reducing inert parts weight to the minimum for the case of solid propellant ballistic missiles may be illustrated in terms of range loss due to excess inert parts weight. For example, let us assume that a two stage IRBM missile is optimized to 0.92 propellant fraction construction and that, for the particular propellant $I_s$, the design results in a range of 1500 mi. Range equations provide for calculating the loss in range resulting from a decrease in the propellant fraction by the addition of inert weight, as follows:

| Reference | Range |
|---|---|
| Optimized condition | 1500 mi |
| 300 lb added to first stage | Approx 1450 mi |
| 100 lb added to second stage | Approx 1430 mi |
| 200 lb added to second stage | Approx 1350 mi |
| 300 lb added to second stage | Approx 1250 mi |

The implication of these figures is that the inert parts weights of the second stage are much more critical than those of the first stage.

The requirement for reducing the inert parts weight to an absolute minimum has focused attention on the weight efficiency of materials used for nozzles and for the casing. At the present stage of development, the potential weight reductions for first-generation systems are greater for nozzles because of the very heavy heat sink materials used for these components. While the potential weight savings for the casing are less than for the nozzles, it is essential that materials of the highest possible strength-to-density ratio be used in order to maximize range. The casings for ballistic missiles actually are thin-walled pressure vessels, varying from 4 to 6 ft in diam and with wall thicknesses in the order of 0.050 to 0.150 in., depending on range and on the stage in question. Early attempts to produce such casings centered on the use of steels having yield strengths in the order of 230,000 to 250,000 psi. Unfortunately, such steels are highly sensitive

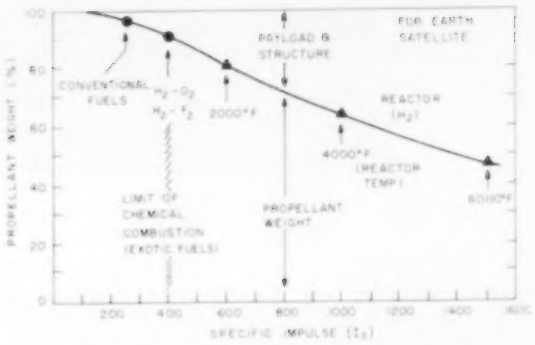



**Fig. 14—Relationship of $I_s$ capabilities of various rockets to pct of launch weight that may be placed in earth orbit.**

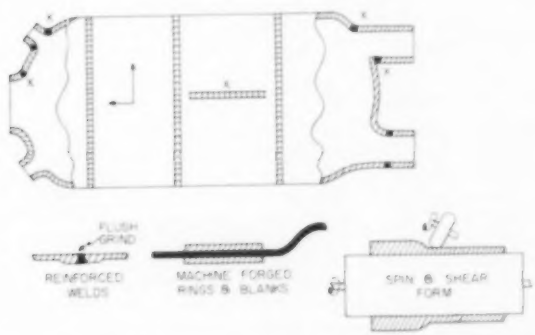



**Fig. 15—Idealized representation of a solid propellant rocket motor casing, illustrating an advanced form of construction based on the elimination of welds (X) from critical positions. Other features include machining of components from forged blanks, shear spinning or forging of components, and weld reinforcement.**

to the presence of minute imperfections or notches, resulting in the development of brittle fracture—shattering—when pressurized to stress levels in the order of 50 pct or less of the yield strength of the material. The design pressures generally involve attaining stresses in the order of 95 pct of the yield strength. Therefore, the failures occurred at stresses that would be tolerable by notch ductile steels of lower yield strength, and no advantage was gained by the use of the higher strength materials. It now appears that a yield strength barrier exists, such that all known steels that are heat treated to yield strengths in excess of approximately 200,000 psi are excessively notch sensitive for use as welded pressure vessels. Metallurgical research may show that this barrier level may be raised, however, this is not certain. Inasmuch as the important parameter is the yield strength to density ratio, attention is also given to titanium alloys that are competitive with high-strength steels because their lower yield strength is offset by the lower density of titanium.

Presently, there are three widely divergent philosophies on fabrication procedures that are required to ensure a combination of minimum weight and maximum reliability for rocket casings.

1) *Perfection construction using notch brittle steels*: This approach is based on a concept of fabrication by shear forming, spinning or cold drawing so as to develop a weld-free, one-piece construction. It is argued that the elimination of all flaws due to welds, and the use of metal sheet of perfect quality—no inclusions or notches—should permit utilization of notch brittle steels of the 230,000 to 250,000 psi yield strength class.

2) *Flaw size control for roll-weld construction*: This approach is based on a concept of restricting the size of largest flaws—by inspection procedures—to that which would not result in enlargement and propagation of a tear or brittle fracture, for the particular service stress level. For steels of the 190,000 psi yield strength level and service stresses near the yield strength, the allowable flaw sizes are quite small and close to the limits of detectability by reliable inspection procedures. The postulated balance between allowable stress level and allowable flaw size that is the essence of this concept, naturally directs this approach to obtaining maximum performance by refinements in flaw inspection procedures and by exacting stress analysis.

3) *Elimination of welds at critical positions*: This concept is considered a practical approach to perfection construction. In practice, it is based on using notch ductile steels—190,000 psi max yield strength—and eliminating welds from positions marked *X* as illustrated in Fig. 15. Forging or shear forming processes are used to produce short cylinders that are welded together to form the body. This procedure eliminates welds in the longitudinal—high stress—direction. The head closures are forged so as to provide integral port openings, thus removing welds from regions of high stresses and bending movements. In essence, perfection construction is used only at the critical positions. Additional precautions may be taken by machining the ring forgings so as to provide reinforcement for the girth weld regions, and thereby reducing the stress level normal to the weld direction.

The concept of perfection construction utilizing notch brittle steels (item 1) is generally considered visionary. Consideration of possibilities of accidental introduction of notches—scratches would be critical—and of stress corrosion cracking, etc., in storage, provide additional arguments against the feasibility of such an approach, if high reliability is required.

Systems that are expected to be operational in the near future are based on either the roll-weld construction with flaw size control (item 2) or the semi-perfection construction (item 3) based on eliminating welds from critical positions. In all cases, the steels used are restricted to the notch ductile variety. At the time of this writing, the crucial question regarding the merits of these two approaches involves the relative reliability of the roll-weld, flaw-size controlled casing in comparison to the inherently more reliable but also more expensive semi-perfection construction casing.

It should be noted that range and reliability trade-offs are involved. A construction that consistently demonstrates capability of withstanding hydrostatic testing to above yield point pressures may logically be considered capable of reliably withstanding near yield point stresses in service. Conversely, a construction that indicates propensities for hydrostatic test failures at near yield point pressures may logically be suspect. Such performance should naturally force a reduction in the allowable service stress level that translates to higher casing weights and reduced range. Because of the large number of casings that are scheduled for fabrication and testing, it is expected that the relative merits of the two competing approaches will be resolved undisputably by failure statistics.

# Recent Metallurgical Developments for Tin

by J. B. Long, Tin Research Institute, Inc.

Tin, one of the earliest metals used by man, continues to enter into a multitude of applications. New alloy developments, improvement of processes which use tin, and encouragement of basic research have opened new horizons in the applications for tin.

The advent of the Space Age has intensified the need for new, versatile metals and alloys. The use of tin and aluminium as alloying elements in titanium provides an alloy with good mechanical properties and higher creep resistance at elevated temperatures. The addition of 15 pct Sn increases the ultimate tensile strength of titanium by 90 pct at room temperature. Low-melting quaternary alloys of tin, indium, lead, and silver have been used for cryogenic circuits, and brazing filler alloys containing tin, nickel, chromium, and silicon are used to join assemblies which function at high temperatures. The resulting joints are capable of resisting intergranular penetration or embrittlement after 400 hr at 1300°F. Techniques have been developed for bonding 20 pct Sn, 78 pct Al, and 2 pct Cu to steel bearing shells. Tin-aluminium bearing metals offer a combination of softness with high fatigue strength, which is amply maintained at temperatures reached by bearings in service.

Gold-tin alloys exhibit good oxidation and corrosion resistance, and have a high thermal heat conductivity; sintered tin bronzes, employed to filter various media, have proved to be strong and corrosion resistant. Tin, in amounts of about 0.1 pct, added to gray and nodular irons eliminates ferrite, resulting in a substantially pearlitic matrix. Additions of 3 to 7 pct Sn and 0.5 pct Al improve the hardenability of silver-copper alloys used in fabricating jewelry. Tin, alloyed with lead and barium, has been used in battery grids, and semiconductor contacts have been enhanced by alloying tin with germanium or silicon.

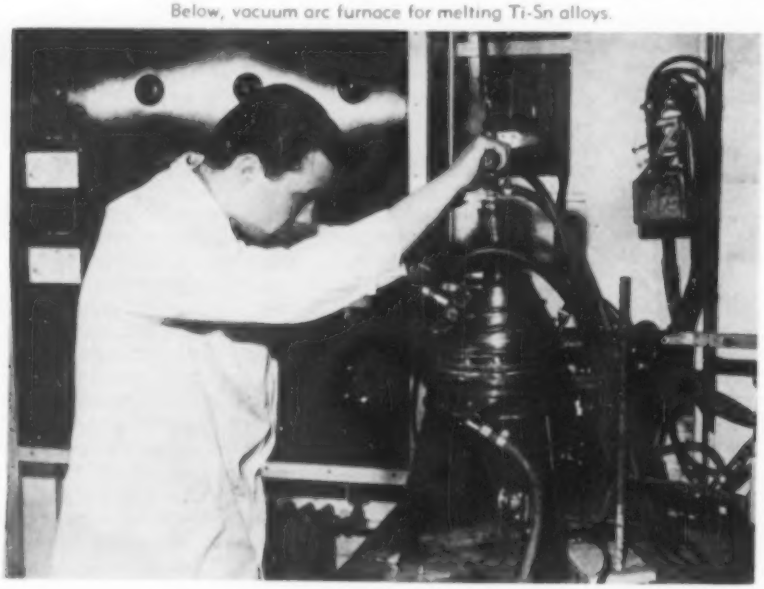
Current demands, such as for lighter gage and wider tinplate have resulted in an increased use of tin. Continuous annealing and faster electrotinning speeds have favored the increased production of electrolytic tinplate in coils. It has been demonstrated that steels with the highest impurities react most rapidly with tin in forming the tin-iron intermediate compound during the flow-melting operation. The intermediate compound itself plays an important role in the internal corrosion resistance of tinplate cans.

Aluminium conductor cables are successfully welded by an exothermic reaction between powdered aluminum, tin oxide, and calcium fluoride flux. Ignition of the powder creates a molten tin alloy which flows into the joint, thus sealing the cable splice. Reliability of soldered joints is a primary concern of the missile and electronic industries. Evaluation programs indicate that hot-dipped or electroplated tin coatings 0.0003 in. thick are superior and least influenced by base metal, undercoat, or storage than other materials tested.

Fundamental research is underway to determine the true behavior of tin in steel. Since the solid solubility of tin in iron is high—approx 10 pct at 200°C—perhaps new alloy steels may be developed to meet the high-strength requirements of industry.

This review does not attempt to do more than outline a few of the achievements of research and technical developments on the use of tin. It is hoped that the selection made here will show, to some extent, that the applicability of modern technologies and scientific research is not restricted to new materials, but extends equally to so ancient a metal as tin.

Below, vacuum arc furnace for melting Ti-Sn alloys.



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# NEWS OF YOUR PROFESSION

## Rocky Mountain Minerals Conference Features Technology and Good Fellowship

The Sixth Annual Rocky Mountain Minerals Conference was held in Salt Lake City, October 5-7, with a registration of approx 300. With an excellent program of papers and seminars on mining and metallurgical subjects, and activities to provide good fellowship, this Regional Conference could well be rated among the best. Headquarters was the Newhouse Hotel; sponsor was the Utah Section of AIME.

For metallurgists, the technical session on Thursday morning, October 6, was of the greatest interest. Here was presented the study made by Kennecott Copper Corp. on *Role of Bacterial Oxidation in Leaching Processes* by E. E. Malouf, project development engineer at the Kennecott Research Center, Salt Lake City. Co-authors were J. D. Prater, head of the hydrometallurgical section, and A. W. Last, chief of the ore dressing section. Bacteria play an important role in a hydrometallurgical process for copper recovery from mine waste at Kennecott's copper projects in Utah. This paper outlined the results of studies which have been in progress for several years with the objective of applying these bacterial oxidation reactions more effectively to such copper recovery.

At this session, a paper on *Electrolytic Tungsten and Molybdenum* was given by D. H. Baker, Jr., and J. B. Zadra, metallurgists with the Metallurgy Research Center of the U.S. Bureau of Mines, Reno, Nev. Among the data it presented, it was noted that yields of tungsten varied between 400 and 650 grams per kw-hr and molybdenum, 300 grams per kw-hr.

Of overall interest was a top-flight *Exploration Symposium* on Friday morning October 7. The difficulties and costs involved in the search for, discovery of, and development of new mines were discussed by a panel of executives of major

*(Continued on page 970)*

## Call for 1961 Dues

Notice is hereby given that dues for the year 1961 are payable Jan. 1, 1961 as follows: Members and Associate Members, $20; Junior Members for the first six years of Junior Membership, $12; and thereafter $17; Student Members (including an annual subscription to a monthly journal), $4.50.

Dues bills were mailed in early November. Prompt payment will assure uninterrupted receipt of the publications desired in 1961. If, for any reason, a bill is not received within a reasonable time, AIME headquarters should be notified.

## British Group of Powder Metallurgists Will Meet Dec. 15-16

The Powder Metallurgy Joint Group of the Iron and Steel Institute (Great Britain) will hold its Winter Meeting on December 15-16 at Church House, Great Smith Street, London.

The group's Spring Meeting will be held at the Royal Commonwealth Society, Northumberland Ave., London, on April 17-18, 1961. One of the features of the meeting will be a discussion of *The Appraisal of Powders For Pressing and Sintering*. The afternoon session on April 17 will be devoted to a discussion of three invited papers dealing with *Techniques for the Evaluation of Powders*. On April 18 there will be a discussion of *The Relationship Between Properties of Powders and Their Pressing and Sintering Behavior*.

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## 1961 Annual Meeting Will Feature Metallurgy in USAF

A symposium on Metallurgy in the Air Force, sponsored by the Institute of Metals Division will be one of the features of the AIME Annual Meeting, which will be held in St. Louis, Mo., February 26-March 2, 1961. The meeting will be held at the Ambassador and the Chase-Park Plaza Hotels.

The Air Force Symposium will be held on Monday, February 27. Other events scheduled for the same day include a session on Electrical Properties of Metals, sponsored by IMD's Chemistry and Physics of Metals Committee, and symposia sponsored by EMD on Reactive Metals, Refractory Metals, Copper, and Lead and Zinc. ISD will sponsor sessions on Gases in Steels and Stainless Steelmaking.

On Sunday afternoon, the Education Committee will present a panel discussion concerning sponsored research at the university and its function.

L. S. Darken, of U. S. Steel Research Laboratories at Monroeville, Pa., will deliver ISD's Howe Lecture on Tuesday morning, February 28, preceded by a session on Physical Chemistry of Slags. The ISD Luncheon will also be held on Tuesday. EMD will sponsor two Tuesday morning sessions: one on zinc and one on uranium. A Titanium Research Abstract Session will be sponsored by IMD on Tuesday morning.

David Turnbull, of General Electric Co., will deliver the Institute of Metals Lecture on Wednesday morning, March 1. In the afternoon, IMD's Chemistry and Physics of Metals Committee will sponsor a symposium on Direct Observations of Imperfections in Crystals. The IMD Semiconductors Committee will sponsor morning and afternoon sessions on Deformation of Semiconductors on Wednesday.

The EMD Luncheon is scheduled for Wednesday at noon. EMD will

*(Continued on page 969)*

# Eastern NOHC Holds 14th Annual Conference In Philadelphia; Cost Control Featured

Cost control, in view of present operations at less-than-capacity rates, was given special attention at the 14th Annual Technical Conference of the Eastern Section of the National Open Hearth Steel Committee. The meeting was held in Philadelphia at the Warwick Hotel on October 28. Registrants numbered 224. The Conference was under the leadership of the Vice-Chairman of the Eastern Section, Russell R. Fayles, manager of steel plants, Lukens Steel Co., Coatesville, Pa.

After his opening remarks, Mr. Fayles introduced the winner of the best-paper award, Spencer Bevins, technical assistant to the open hearth department, Steelton plant, Bethlehem Steel Co. In his paper, *Maximum Hot Metal Charges at Steelton*, Mr. Bevins described experiments in a 280-ton furnace on maximum hot-metal charges and their effect in increasing production and decreasing fuel consumption.

The lead-off paper in the formal technical program on *Oxygen Lance Experiments at Sparrows Point Plant* was presented by D. F. Brion, supervisor, process metallurgy div., research department, Bethlehem Steel Co. Co-author was Richard F. Urban, assistant to open hearth superintendent, Sparrows Point plant, Bethlehem Steel Co. The authors discussed the effect of oxygen on tap-to-tap time, life of refractories, and steel quality. The position of the end of the oxygen lances, 4 or 5 in. above the slag-metal interface, gives minimum splashing and fumes.

*Open Hearth Checkerboard Roof*, written by R. C. Oswald, open hearth superintendent, Sharon Steel Co., was read by William A. Parks, assistant open hearth superintendent. The conclusion was drawn that the checkerboard roof is less expensive than the all-basic roof. Combined with a spraying technique, increased roof life is obtained.

*Techniques for Rebuilding Open Hearth Furnaces* by Carl F. Bessent, supervisor of mechanical maintenance, Sparrows Point plant Bethlehem Steel Co., described practices at the No. 4 shop at Sparrows Point where furnaces are of very large capacity. The premise was that a major factor in raising production costs is the time out for furnace repairs; hence, planning to achieve the maximum in continuous furnace operations was advocated. Chairmen of the morning session were John J. Hannigan, open hearth superintendent, Alan Wood Steel Co., and Horace W. Potter, assistant superintendent of melting, Lukens Steel Co.

After a luncheon interlude, Howard A. Parker, div. superintendent, open hearths, Fairless works, U. S. Steel Corp., reported on a *European-Asiatic Trip—Spring 1960*. The objectives were to study the development of basic roofs and techniques of oxygen use at several steel plants in Japan, Italy, and Germany. Featured at the afternoon session was a panel discussion on *Cost Control*. With Frank Broglie, technical director of Bethlehem Steel Co., as moderator, the discussion was begun by John J. Hannigan of Alan Wood Steel Co. talking on *Yields*. He told of a cost-control system installed in 1958 and the relation of costs to yields. Herbert H. Haas of Colorado Fuel & Iron Co. described *Open Hearth Services* at the Roebling plant. The following services are considered as part of ingot costs: locomotive switching, slag handling, metallurgical laboratory, ingot storage yard, and maintenance craft shop service.

*Refractories* were discussed by William Wilhelm, Bethlehem Steel Co. Increasing refractory costs are due in part to the increasing use of more expensive refractories, *e.g.*, basic brick and high-alumina refractories. Howard A. Parker, U. S. Steel Corp., speaking on *Bottom Refractories*, described the cost-cutting practices followed at the Yawata Steel Works in Japan.

*Minimum Hot-Top Cost* was the subject of a talk by H. W. Potter, Lukens Steel Co. In a theoretically perfect hot top, only 3½ pct extra metal would be needed to *feed* the ingot. Comparative percentages of extra metal were determined for different types of hot tops, as well as comparative costs. Special attention was accorded *Tiger* hot tops, exothermic hot top slabs, and sand-cement hot tops. Concluding remarks on *Cost Control Generalities* were given by George S. Baldwin, melting superintendent Standard Steel Works, div. of Baldwin-Lima-Hamilton. Success in cost control is dependent upon attention to the *little things in steelmaking*, and on the cooperation of pit foremen, stock bosses, and melter foremen.

At the Fellowship Dinner, entertainment was provided by the Fairless Works Male Chorus, and by television singer, Julia Cummings.

Contributing to the success of the 14th Eastern Section Conference were Russell R. Fayles, Acting Chairman (during the absence in Europe of Chairman Clyde B. Jenni, chief metallurgist, General Steel Castings Corp.) and Secretary-Treasurer, Robert G. Waite, metallurgical engineer, General Steel Castings Corp. Responsible for organizing the technical program was Gardner Blythe, open hearth superintendent, J. A. Roebling's Sons Corp. In charge of the Suppliers' Committee and responsible for the entertainment was J. W. Corriston, district sales manager, E. J. Lavino & Co. Credit is also due the man-behind-the-scenes, C. D. Moore, vice president, G. & W. H. Corson, Inc.

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## Univ. of Arizona Honors Four Members of Mining Industry

Four members of the mining industry received the University of Arizona's 75th Anniversary Medallion of Merit on October 17. Presentations were made at the dinner of the University of Arizona Symposium on Surface Mining Practices in Tuscon. Those awarded the medallion are:

**Frank H. Buchella** of San Manuel, Ariz., vice president of both the Magma Copper Co., and San Manuel Copper Co., and general manager of the latter. He has served as design engineer for the Utah Copper Co., and the Nevada Consolidated Copper Co., and also as consulting engineer and assistant general manager of the Chino Mines div., Kennecott Copper Corp. He has been with the San Manuel Copper Co. since 1948.

**Darrel Gardner** of Superior, Ariz., general manager of Magna Copper Co. He has been associated with Magma since 1926, serving as level boss, mine foreman, mine superintendent, and assistant general manager prior to his appointment as general manager in 1958.

**John A. Ware** president of Tarr, McComb & Ware, of Prescott, Ariz. The medallion was given in memory of Mr. Ware's father, Allen E. Ware, a pioneer in mining and the mining supply and equipment field.

**Carrol P. Donohoe** president and general manager of Cananea Consolidated Copper Co., of Cananea, Sonora, Mexico. After serving with Anaconda at the Montana Reduction works and the Basic Magnesium plant in Henderson, Nev., he joined Cananea in 1944.

# AROUND THE SECTIONS

**El Paso** section held a meeting at the Hotel Cortez on October 13 honoring AIME President, Joseph L. Gillson, and Mrs. Gillson. Dr. Gillson spoke on *Archeology in Mexico*.

**Boston** section, AIME, has announced its meeting program for 1961. The January 9 meeting will feature a talk on *Materials for the Electronic Industry* by William Kohl, staff consultant at Sylvania Electric Products Co., and currently visiting lecturer at Stanford University. At the February 6 meeting, James L. Martin, director, Ordinance Materials Research Office, Watertown Arsenal, will speak on *Research in Government*. Herbert M. Strong, research physicist with General Electric Co., will speak on *Current Research on the Effects of High Pressure* at the meeting on March 6. Students Night will be held on April 20, with Gordon S. Brown, dean of the school of Engineering at M.I.T., speaking on *Ferment in Engineering Education*. The meeting on May 8 will be Ladies Night. Thomas Gold, chairman of the Astronomy Department at Cornell University will speak on *The Object of Space Research*.

**Western** section, NOHC, held its first meeting of the year on October 19, at the Rodger Young Auditorium in Los Angeles. Speakers for the evening were R. C. Barrett and Roy Armstrong, who discussed the use of oxygen in the steel industry.

**Buffalo** section, NOHC, held its eleventh annual fall meeting on November 15 at the Hotel Statler Hilton. The first part of the meeting was a tour of the No. 3 Open Hearth Plant of Bethlehem Steel Co. The technical sessions began in the afternoon and included presentation of a paper, *Synthetic Bessemer Steel*, by Frank Sadler, open hearth metallurgist, Republic Steel Corp. The paper will be submitted for the McKune Award.

A session on *Pit Practices* included discussions of *Proper Teeming* by W. Redmond, Republic Steel Corp.; *Outside Nozzle Setting* by Charles Hunt, Dofasco; *Capping Practice on Large Molds* by William McShane, Bethlehem Steel Co.; and *Ladle Brick, Stopper Rods and Sleeves* by George Newton, Steel Co. of Canada, Ltd. A. K. Moore, superintendent of open hearth at Stelco, presented a paper on the *Future of Open Hearth Steelmaking*.

**Pittsburgh** section, AIME, held an all-section business meeting on September 30 at the Penn-Sheraton Hotel. The by-laws of the group were presented for approval. An Off-The-Record dinner dance was held at the Penn-Sheraton on November 3.

**Montana** section, AIME, will hold its Annual Meeting in Butte on the evening of December 10. There will be an election of officers and a dinner dance. AIME president-elect, R. R. McNaughton, will attend the meeting.

**Ohio Valley** section, AIME, held National Officers' and Ladies' Night on October 27 at the Pick-Fort Hayes Hotel in Columbus. R. R. McNaughton, president-elect of AIME spoke on his experiences with the Consolidated Mining and Smelting Co., of Canada. A dinner-meeting is scheduled for December 1, at the Olentangy Inn. One of the features of the meeting will be a talk by W. H. Congleton on *New Businesses Based on Technological Advances*.

**Philadelphia** section held Student Award Night at the Presidential Apartments of the Madison House on October 13. Awards were made for papers in the Undergraduate Division; first place went to Paul O. Hagerman for his paper, *Retrogression in Commercially-Produced 2024 Duralumen Alloy*. Mr. Hagerman, a 1960 graduate of Drexel Institute of Technology, is now with the metals and control div. of the Texas Instrument Co. *Tensile Properties of Thin Aluminum Foil*, by Melvin Goldberg, a 1960 graduate of the University of Pennsylvania, was awarded second place. Mr. Goldberg is teaching physics and mathematics at the Mayflower School in Nigeria. Following the award period, a discussion on Creativity, was conducted by Leopold Pessel, section chairman.

**New York** section of the AIME met on October 19 at the Mining Club. Mining industry research policy was discussed by Clyde Williams, head of his own research firm and a former director of Battelle Memorial Institute; A. B. Kinzel, vice president of research, Union Carbide Corp.; Arthur Phillips, of Asarco; Charles Moore of the Copper Products Development Assn.; and Schrade Radtke of the American Zinc Institute and of the Lead Industries Association.

Refractory metals, even when pure, are unsuitable for many uses until their properties are improved or modified, Dr. Kinzel said, and this calls for basic research. To be successful in research, one must keep pace with one's competitors. About 80 pct of research information is in public domain, but it is useless unless one is in a position to take advantage of it. Dr. Kinzel declared that mining needs more imagination and that every phase of mining can be either improved or eliminated.

Dr. Moore said that copper is not a commodity, but a raw material, which must be used wherever and however possible. He noted that copper may find possible future uses as a catalyst, or in thin-sheet copper foil in conjunction with another metal. He also mentioned the field of copper organics but noted that little work has been done.

**Tucson** subsection met on October 19 at Holiday Inn in Tucson. The guest speaker was Victor Verity, Tucson mining engineer and attorney. He spoke on contributions of the Rocky Mountain Mineral Law Foundation. Among guests at the meeting were Willis R. Dees, a trustee of the Foundation, and Rixford A. Beals, editorial director of MINING ENGINEERING. Sixty-four members and guests attended the meeting.

## EDUCATION

*(Continued from page 918)*

is to develop an understanding of the complexities involved in the fracture of inorganic, non-metallic ceramics. Researchers will try to find out why ceramic materials fail, how they fail, and what methods can be developed to improve their reliability.

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# STUDENT NEWS

Attending the Metals Club meeting at Illinois Institute of Technology were (l to r), Jay B. Schneider, secretary of the Metals Club; M. L. Sludski, speaker; Roy W. Lobenhofer, president; L. F. Mondolfo, faculty advisor; and Fred B. Gazella, vice president.

## Illinois Institute of Technology

The Metals Club at Illinois Institute of Technology met October 11 to hear M. L. Sludski of Revere Copper & Brass Co., give the first of a series of talks on *The Role of the Metallurgical Engineer in Industry and Research*. Mr. Sludski discussed the role of metallurgical engineers in nonferrous metals production. At the November 15 meeting O. J. Barnett of Armour Research Foundation discussed *The Role of the Metallurgical Engineer in Research and Development*. The next meeting will be December 6.

## University of Michigan

Michigan Metallurgical Societies met October 4, with 40 members attending. R. C. Taylor, professor of chemistry, spoke on *The Use of Infra-Red and Roman Spectra in Structure Determination*. At the meeting held on October 18, Peter Debje discussed the Debje Scherrer Method of X-Ray Diffraction.

The first meeting of the Minerals Industries Society at the University of Illinois was held on October 11. Officers of the organization are (standing, l to r), George Vytanovych, secretary; Robert Wittman, president; William Bottomley, vice-president; Walter Collins, treasurer; and Ronald Bradle, Engineering Council Representative. Seated are Dr. B. G. Ricketts, professor and acting head of the Dept. of Mining and Metallurgical Engineering, and G. R. Eadle, associate professor of mining and engineering, faculty advisor.

**NEW STUDENT MEMBERS**

**University of Arizona**
Shea, Joseph D.
Stephens, Arthur W.
Stone, Bruce H.

**Polytechnic Institute of Brooklyn**
Flescher, Albert L.
Gold, Edward
Meiseles, Gilbert N.
Montelbano, Thomas O.
Saxe, Richard S.
Scheurer, Raymond L.
Tarshis, Lemuel A.

**Illinois Institute of Tech.**
DeBall, Donald J.
Schneider, Jay B.

**University of Illinois**
Goetsch, Glenn R.

**University of Kentucky**
Bowley, James G.

**Melbourne (Australia) University**
Blanks, Ronald F.

**Michigan College of Mining & Tech.**
Tardiff, George E.

**University of Minnesota**
Fukuhara, Yoshihiro

**Montana School of Mines**
Beardslee, Elvin H.
Blomstedt, Bruce D.
Cesarani, John E.
Coghlan, William A.
Garey, Robert W. Jr.
Keane, Joseph M.
Trbovich, Daniel E.

**City College of New York**
Prager, Murray I.

**University of Oklahoma**
Mehdizadeh, Parviz (Graduate School)

**Pennsylvania State University**
Johnson, Stephen G.
Lafferty, William D.

**University of Pennsylvania**
Klein, Victor
Sezaki, Kazuo

**University of Pittsburgh**
Staley, James T.

**Rensselaer Polytechnic Institute**
Koch, Eric

**South Dakota School of Mines & Tech.**
Johnson, Dennis M.
Jones, Chadwic E.
O'Farrell, Robert J.
Sherwood, LeVaught L.
Unruh, Stacy A.

**University of Utah**
Olsen, Charles A.

**University of Washington**
Bivens, Jon A.

**University of Wisconsin**
Huff, James W.
Stueber, Richard J.

**Yale University**
Hayes, Charles E.

## Lafayette College

Lafayette's John Markle Society met October 27. After a general business meeting, Boice McCain, senior metallurgical engineer told the group about his experiences working in a steel foundry in Denmark during the summer. About 20 members attended the meeting.

## Annual Meeting . . .

*(Continued from page 965)*

sponsor a two-part symposium on Hydrometallurgy. Symposia on Thermodynamics of Liquid Iron and Applications of Thermodynamics will be sponsored by ISD.

A. M. Gaudin, professor of mining engineering at Massachusetts Institute of Technology will present the EMD Lecture on Thursday, March 2. EMD will sponsor symposia on Ceramics; Refractories in Nonferrous Furnace Technology; and Pyrometallurgy.

The Iron and Steel Division will sponsor a Thursday morning session on Steelmaking, which will include papers on Desulfurization in the Open Hearth, Acid Oxygen Steelmaking, and a Progress Report on the Oxygen Lime Process. A session on Blast Furnace Technology is scheduled for Thursday afternoon.

A symposium on Kinetics and Design will be jointly sponsored by MBD, ISD, and EMD on Wednesday, March 1. The morning session will include papers on Reaction Kinetics in Metallurgy by Henry Eyring, Mass Transfer by T. B. King, Theory and Application of Model Studies by Kun Li, and Liquid Extraction Principles and Application to Nuclear Fuel Processing by David Miller.

The afternoon session will feature papers on Conditioning Rate Studies of Iron Ore, Alloy-Salt Exchange Reactions, Kinetics of Reduction of Magnesite with Hydrogen and Hydrogen-Water Vapor Mixtures, and Kinetics of Flotation.

## Books

*(Continued from page 896)*

problems of corrosion are not discussed. Included are classification of inhibitors and the laws governing their action, concepts of the mechanism of protective action of inhibitors, and detailed discussion of inhibitors of atmospheric corrosion, and corrosion in solutions of acids and alkalies, in water, and in aqueous solutions of salts. Appendices contain information on pickling, boiler cleaning, and rust removal, and there is a useful index of inhibitors. •

**Oxygen in Steelmaking**—Bibliographical Series 22 of the Iron and Steel Institute: 1946-1949, 127 pp., approx $4.25, 1960—This bibliography, which contains some 700 abstracts, should prove valuable to all those concerned with oxygen steelmaking. Supplementary bibliographies will be issued at intervals.

Order from The Iron and Steel Institute, 4 Grosvenor Gardens London SW 1, England. Consult them for exact price.

## MEMBERSHIP

*Proposed for Membership*
*Metallurgical Society of AIME*

*Total AIME members on October 30, 1960, was 34,502; in addition 2,704 Student Members were enrolled.*

*ADMISSIONS COMMITTEE*

*W. L. Brytczuk, Chairman; S. C. Carapella, Jr.; J. W. Hanley; T. D. Jones; H. C. Larson; Harold Margolin; Shadburn Marshall.*

*The Institute desires to extend its privileges to every person to whom it can be of service, but does not desire as members persons who are unqualified. Institute members are urged to review this list as soon as possible and immediately to inform the Secretary's office if names of people are found who are known to be unqualified for AIME membership.*

**Members**

Arnold, D. S., Trona, Calif.
Axelson, Emil A., Pittsburgh, Pa.
Bertrand, Henri M., Paris, France
Fiorentino, Robert J., Columbus, Ohio
Gregory, Frank G., Lackawanna, N. Y.
Hime, Mervin G. G., Rio de Janeiro, Brazil
Howard, Robert T., Chicago, Ill.
Ikeno, Teruo, Murroran, Hokkaido, Japan
Klodt, Donald T., Denver, Colo.
Kochl, Ernst, Linz, Austria
Kolbe, Carl L., Schenectady, N. Y.
Krsek, George R., Rahway, N. J.
Lieberman, Salvador E., Campana, Argentina
McCurdy, Hugh R., Columbus, Ohio
Mitchell, John W., Charlottesville, Va.
Nelson, Richard C., Braintree, Mass.
Palmer, Howard R., Henderson, Nev.
Poslawski, Roman Post, Montreal, Que., Canada
Rinesch, Rudolph, Linz, Austria
Roe, Frank C., Perth Amboy, N. J.
Sakui, Seita, Tokyo, Japan
Sawyer, Herbert F., Concord, Mass.
Schaden, Herbert P. F., Linz, Austria
Schulz, Gerhard S., Rangoon, Burma
Slivka, Marion J., Scotia, N. Y.
Solow, Max, Middle River, Md.
Wagner, Herbert J., Columbus, Ohio
Weitzer, Helmut, Linz, Austria
Wolf, James S., Cleveland, Ohio
Wright, Robert L., Rolla, Mo.
Wroten, William L. Jr., Perth Amboy, N. J.

**Associate Members**

Elms, Robert L., Bedford, Ind.
Kolb, Fred L., Kirkwood, Mo.
O'Reilly, John E., Chicago, Ill.

**Junior Members**

Breznyak, Edward J., Warrensville Hts., Ohio
Cooper, Thomas D., Dayton, Ohio
Cosentino, Leonard C., Cleveland, Ohio
Edwards, Ralph P., Youngstown, Ohio
Gregory, Donald P., Old Saybrook, Conn.
Lewis, Allen I., Pittsburgh, Pa.
Moore, David B., Cleveland, Ohio
Northrup, Jack B., Greenwood, Ind.
Schoenfeld, William J., Bridgeville, Pa.

**REINSTATEMENT—MEMBER**

Kimzey, W. Dwight, Columbia Falls, Ind.
White, Aaron M., Waban, Mass.

**REINSTATEMENT—CHANGE OF STATUS**

**Junior to Member**

Polonis, Douglas H., Seattle, Wash.

**Associate to Member**

Sontz, Arthur, Chicago, Ill.

**Student to Member**

Fagin, Karl W., Stockbridge, Mass.
Rowe, George H., Windsor Locks, Conn.
Van Thyne, R. J., Chicago, Ill.

**CHANGE OF STATUS**

**Associate to Member**

Dodson, William W., Detroit, Mich.

**Junior to Associate**

Haw, Sherwood G., Waynesburg, Ohio

## C. H. Moore Discusses Program of CPDA

Charles H. Moore, technical director of the Copper Products Development Assn. (CPDA) spoke at a meeting of the Connecticut section of AIME on October 21. Dr. Moore discussed the organization, objectives, and program of CPDA, an organization formed by producers for the purpose of conducting research to find new and improved uses for copper and copper alloys.

CPDA's research operations are carried out through contracts or grants to research institutes, commercial and corporate laboratories, university foundations, and other groups which do contract or fellowship research. At present there are five projects underway: two at Battelle Memorial Institute, one at Southwest Research Institute, one at the British Nonferrous Metals Research Assn., and one at Chase Brass & Copper Co. About a dozen other projects are under consideration.

The 1961 research program of CPDA will be concerned with four types of projects; they are: 1) *Copper as a chemical raw material*—projects designed to take advantage of the copper ion's affinity for nonmetallic ions and its notorious tendency to migrate; 2) *Copper as a mechanical material*—projects designed to yield products that are unaffected by the copper ion's activity; 3) *Surface chemistry*—projects designed to suppress or render ineffectural the activity and mobility of the copper ion; and 4) *Atomic chemistry*—projects aimed at the structural modification of the basic copper atom.

Discussing current projects, Dr. Moore mentioned efforts to develop a protective film on copper products through the selective surface oxidation of minor constituents. There are several projects concerned with coatings to prevent tarnish.

Speaking of CPDA's approach to research, Dr. Moore said, "We envision the separation of our efforts into categories based on the final application or use of the material. It is, thus, a fundamental approach designed to yield a specific end product or group of products."

## NECROLOGY

| Date Elected | Name | Date of Death |
|---|---|---|
| 1941 | Cole, Fraser M. | June 1, 1960 |
| 1933 | Davidson, Donald M. | Sept. 15, 1960 |
| 1941 | Doerr, Kuno, Jr. | Oct. 13, 1960 |
| 1901 | Goransson, K. F. (Legion of Honor) | Unknown |
| 1896 | Henderson, J. McC. (Legion of Honor | Aug. 2, 1960 |
| 1916 | Logan, William W. | Sept. 6, 1960 |
| 1920 | Moffitt, Robt. C. | Sept. 21, 1960 |
| 1925 | Pallanch, Rollin A. | Sept. 29, 1960 |
| 1951 | Stevens, E. H. | Unknown |

## Rocky Mountain Minerals Conference

*(Continued from page 965)*

mining and metals companies. James Boyd, president of Copper Range Co., served as moderator. He defined the objective of the symposium—to present information on the technical difficulties of bringing mines into successful production. The first speaker, Francis Cameron, president of St. Joseph Lead Co., defined the general principles that a metal mining company must consider in reaching a decision whether to undertake a new mining venture. C. P. Pollack, exploration manager, American Smelting & Refining Co., cited the example of the recent Toquepala project of the Southern Peru Copper Corp. to illustrate the requirements of working capital and engineering skill for successful exploration and production of a major mining endeavor. Sidney S. Goodwin, vice-president, New Jersey Zinc Co., gave dollar and cents answers to the question of "how much should we spend for exploration?" He pointed out that a mining company, to continue in business, must either have an inexhaustible supply of ore, or must explore and find new ore sources. Basic to achieving success in exploration is: 1) continuity of effort, and 2) work handled by a competent staff, supported by an informed management. The last speaker on the panel, Charles C. Huston, president of C. C. Huston and Associates, Toronto, Canada, described the areas of exploration and of mining in Canada today. He pointed out that mining brings new wealth to a country. Moderator Boyd said, as a conclusion to the symposium, that if the US is to remain strong as an industrial country, then the Government, through proper tax laws, must give encouragement to the mining and metal industries.

On Thursday afternoon, October 6, a paper was presented on *Mining the Sea Floor* by L. E. Shaffer, professor of Mining, Dept. of Mineral Technology, University of California, Berkeley. Because our normal supplies of some metals and minerals are dwindling, we must consider other sources. For example, certain areas of the sea floor are covered with strange egg-shaped nodules or concretionary blobs composed of manganese and iron oxides, with minor but important amounts of copper, cobalt, and nickel. The origin is hypothesized to be the result of a complex ion-exchange process in the sea water where, during centuries of time, hydrous metal ions precipitated and built up around debris on the sea floor. In 1960, a Scripps Institution of Oceanography expedition into the Gulf of Lower California resulted in the discovery of a deposit of nearly pure manganese dioxide nodules. As battery-grade, this pure manganese dioxide should be worth several hundred dollars per ton. The feasibility of a mining venture may well be worth considering.

W. J. Staten of Westinghouse Electric Corp., spoke on the *Pressurized Water Reactor and Its Place in Today's Utility System* on the opening day, October 5. The speaker pointed out that one of the important differences between nuclear and conventional plants is that the former run higher in initial capital cost; thus, to be competitive, fuel costs must be lower in the nuclear plant. This makes nuclear plants the logical candidates for the special and important role of base load generation in utility system operations. Conventional plants, with their lower capital costs, are then in an excellent position to serve the intermediate and peaking loads of the system. The speaker concluded that it appears that for some time to come, only nuclear plants of very large size will prove competitive.

The other excellent technical papers presented at the three-day meeting were of primary interest to mining engineers.

A Conference feature was a plant tour on Friday afternoon, October 7, to Hercules Powder Co.'s Bacchus plant. Here is carried on the design, development, and manufacture of large rockets and rocket propellants —a multimillion-dollar facility. In addition to inspecting such exotic developments as the third-stage rocket motor for the ICBM Minuteman, the visitors also saw facilities for the more prosaic manufacture of dynamite and nitroglycerine. The history of Bacchus since 1913 has paralleled the development of Bingham Canyon and other mines in Utah and central Nevada, with ever-increasing requirements for industrial explosives.

Social functions as a forum for good fellowship played an important part in making the Sixth Rocky Mountain Minerals Conference a notable success. Ladies were treated to such special events as a Coffee Party, Luncheon, and Fashion Show. At the Welcoming Luncheon on October 5, the Conference was addressed by Major General Maxwell E. Rich, Adjutant General of the Utah National Guard, on *The Threat We Face*. That evening, the mining companies and suppliers provided a cocktail party.

The Minerals Luncheon was held on October 6, with Joseph L. Gillson, President of AIME, the featured speaker. Dr. Gillson discussed some of AIME's current problems: 1) bigness and diversity with 36,000 members in three Societies; 2) adequate financing of the new United Engineering Center; 3) possible reorganization of the Council of Section Delegates; 4) obtaining of adequate publicity for the Institute and its units; 5) licensing and registration of engineers. W. B. Stephenson, President-Elect of the Society of Mining Engineers, previewed the International Symposium on Agglomeration (Philadelphia, April 12-14, 1961). J. D. Vincent described plans for the Froth Flotation Conference (Denver, September 17-20, 1961). Among those introduced at the head table were Ronald R. McNaughton, President-Elect of AIME, and Carleton C. Long, President of The Metallurgical Society.

The final day was greeted by a *Miner's Breakfast*. The Conference ended with an informal Dinner Dance at the Newhouse Hotel. Many continued on to Las Vegas, Nevada, for the American Mining Congress the following week.

Heading an energetic Conference Committee were Chairman John M. Ehrhorn, U. S. Smelting, Refining & Mining Co., Salt Lake City, and Vice-Chairman H. E. Wright, Galigher Co., Salt Lake City. Norman L. Weiss, American Smelting & Refining Co., is chairman of the Utah Section.

RWS

## Personals

*(Continued from page 917)*

**Stanmore V. Wilson** has been elected president of U.S. Bronze Powders Inc., of Flemington, N. J.

**George J. Peer** has been named sales manager, furnace products, of Basic, Inc., Cleveland, Ohio. **D. Bedell Baxter** is the new sales manager for the company's central district in Cleveland.

**William Pfann** of Bell Telephone Laboratories will receive the 1960 Professional Progress Award of the American Institute of Chemical Engineers. Consisting of an award and $1000, the presentation will be made in Washington Dec. 6. Mr. Pfann is the inventor of the Zone Melting process which made semiconductors possible. He received the IMD's Mathewson Award in 1955.

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# Coming Events

Nov. 30-Dec. 2, AIME 18th Electric Furnace Conference, Morrison Hotel, Chicago.

Jan. 8-12, 1961, Symposium on Thermoelectric Energy Conversion, Statler-Hilton Hotel, Dallas, Texas.

Jan. 18, 1961, Western Section, NOHC, Roger Young Auditorium, Los Angeles.

Jan. 18, 1961, Conference on Bar and Shaped Products, sponsored by Mechanical Working Committee of The Metallurgical Society, Penn-Sheraton Hotel, Pittsburgh.

Feb. 1, 1961, N. Y. Section, Powder Metallurgy Group, Brass Rail Restaurant, 43rd St. & Fifth Ave., New York.

Feb. 10, 1961, Southwestern Section, NOHC, Annual All-Day Meeting, Hotel Lennox, St. Louis.

Feb. 26-March 2, 1961, AIME Annual Meeting, Ambassador and Chase-Park Plaza Hotels, St. Louis, Mo.

Mar. 13-14, 1961, 59th Annual Meeting, Steel Founders' Society of America, Drake Hotel, Chicago.

Mar. 20-24, 1961, Western Metal Exposition & Congress, Pan Pacific Auditorium, Los Angeles.

Apr. 10-12, 1961, 44th National Open Hearth Steel Conference and Blast Furnace, Coke Oven, and Raw Materials Conference, Sheraton Hotel, Philadelphia.

Apr. 12-14, 1961, AIME International Symposium on Agglomeration, Sheraton Hotel, Philadelphia.

Apr. 24-25, 1961, AIME Southwest Minerals Industry Conference, Stardust Hotel, Las Vegas, Nev.

Apr. 26-27, 1961, Cleveland Section and The Metallurgical Society, Technical Conference on High Temperature Materials, Hotel Carter, Cleveland.

May 18-19, 1961, AIME 15th New England Regional Conference, Hotel Van Curler, Schenectady, N. Y.

Aug. 30-Sept. 1, 1691, AIME Third Technical Conference on Semiconductors, Ambassador Hotel, Los Angeles.

Oct. 17-Nov. 7, 1961, Visit of the Iron & Steel Institute (Great Britain) to the United States.

Oct. 23-26, 1961, Fall Meeting of The Metallurgical Society of AIME, Pick-Fort Shelby Hotel, Detroit.

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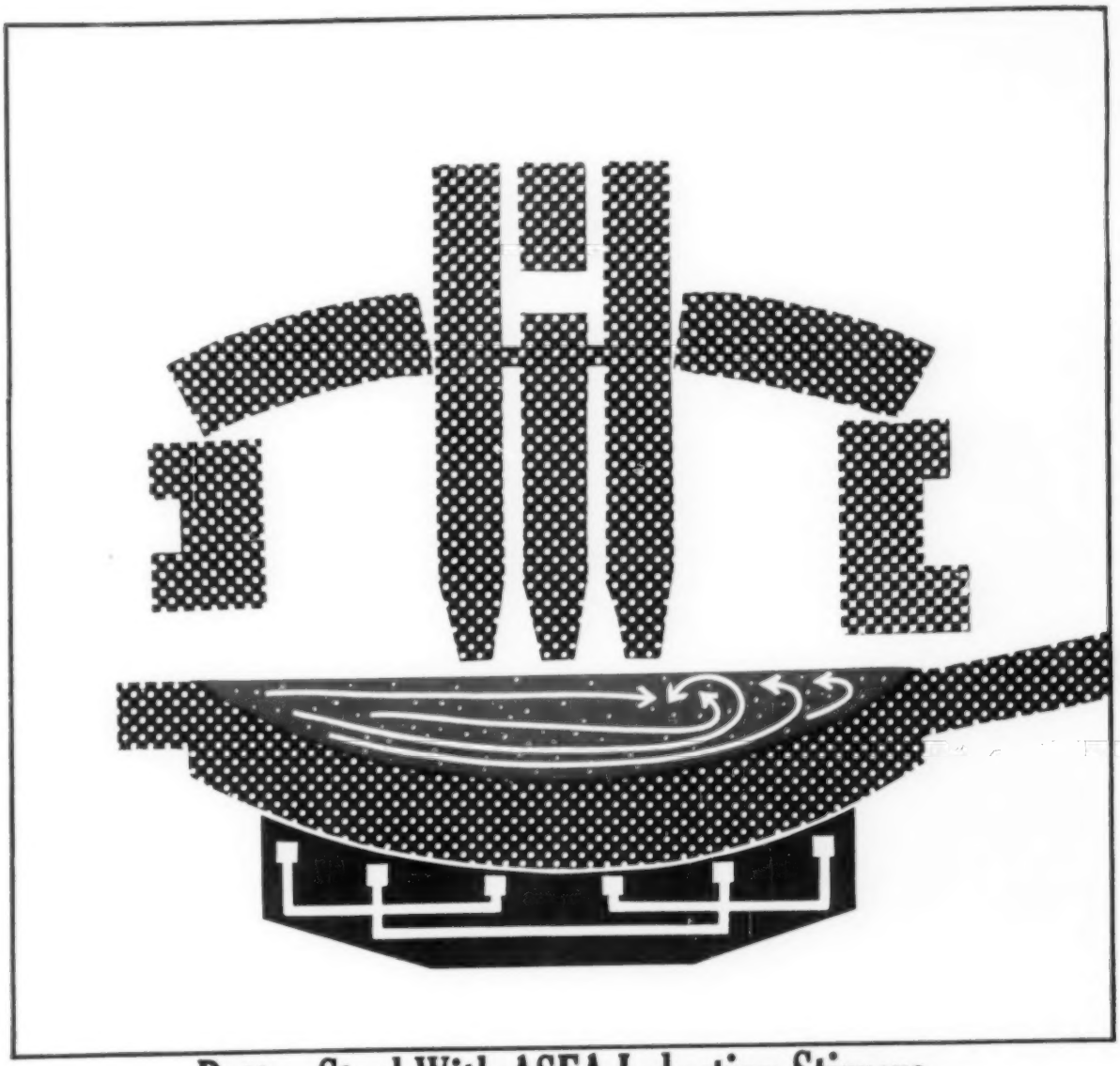

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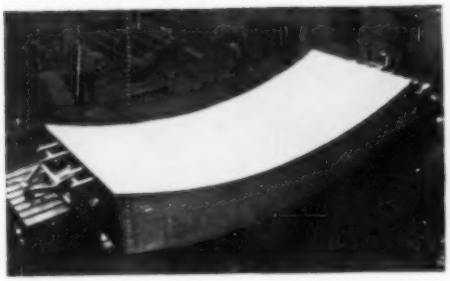

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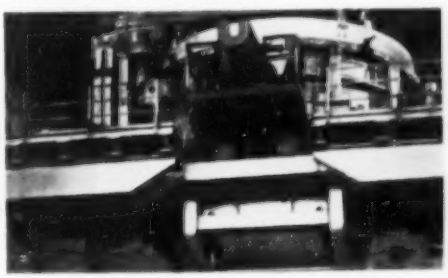

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